2DLX

Line Differential Protection IED

Instructions Manual for **2DLX** Models
M2DLXA1905Iv02

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Chapter 1.

Description and Start-Up

1.1 Functions

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The IED generically designated as **DLX** combines all the necessary functions required for full protection, control and metering of line positions. These IEDs use the most advanced digital technology based on powerful microprocessors and DSP's, and incorporates Differential Protection, Directional and Non-Directional Overcurrent Protection, Over / Undervoltage and Over / Underfrequency Protection, Recloser, Synchronism Detection, Thermal Image Protection and more.

DLX systems are of application in high and medium voltage lines, no matter whether overhead, underground or a combination of both.

DLX relays combine Differential and Directional Comparison elements with other Current Measurement elements (Phase, Ground, Sensitive Ground and Negative Sequence Instantaneous and Time Overcurrent; Thermal Image; Breaker Failure; Open Phase Detector and CT Supervision Element) and, in **DLX-B** relays, with Voltage Measurement elements (Phase Over/Under Voltage and Ground Overvoltage; Dead Line and Fuse Failure Detector) and Frequency Measurement elements (Over/Under Frequency and Frequency Rate-of-Change).

Protection Schemes can be added, for **DLX-B** Models, to Directional Overcurrent elements for instantaneous tripping along the entire length of the line.

The **DLX-B** relay allows for Single-Phase or Three-Phase tripping (it can be set to three phase tripping only) using Single/Three-Phase Tripping Logic. Tripping of **DLX-A** models is always three-phase.

The **DLX-B** Recloser allows for reclosing either Single-Phase or Three-Phase trips or both; four different modes of reclosing operation being possible in order to do so. Furthermore, prior to a Reclosing Command, it will optionally check synchronism, and this information can be supplied by the equipment Synchronism Unit. **DLX-A** relays can perform 4 reclosing attempts.

DLX relays also include Command Logic to perform breaking and closing operations and generate from these operations as well as from Tripping and Reclosing Commands, Trip and Close Failure information.

This Instruction Manual refers to different models whose particular features are stated on paragraph 1.5, Model Selection.

1.1.1 Differential Units

1.1.1.a Phase Differential Unit

DLX relays incorporate segregated Phase Differential Elements with dual slope percentage restraint characteristic. The Differential Element compensates for the difference between CT transformation ratios. On the other hand, it includes an algorithm for capacitive current compensation in order to keep a good sensitivity in very long cables and overhead lines.

1.1.1.b Ground and Negative Sequence Differential Units

These elements increase the sensitivity on internal faults with little infeed, as for very resistive faults, which may not be detected by the phase differential element.

Ground and Negative Sequence Differential Elements could be set to issue single phase trips thanks to the relay Phase Selector.

1.1.1.c Communications between Relays

DLX relays incorporate two ports for the communications required by the differential function, with monomode fiber optic interface and ST connector. Port optic gain is 20dB. The distance reached without repeaters is about 24km with fiber 9/125μm and 1310nm wave length.

The number of ports incorporated allows for the use of two redundant communications channels. Both channels will be continuously monitored, so that if a failure is detected in the channel being used, it automatically switches to the other channel.

The baud rate between two **DLX** relays is 64 Kbits/s and the data transferred includes not only analog magnitudes required to operate the differential and directional comparison elements, but digital signals, 14 of which are user programmable (Virtual Inputs / Outputs), which makes it possible to create protection schemes.

Clock synchronization between two **DLX** relays, necessary for the correct operation of differential elements, may be carried out both by communications and GPS. In this latter case, the operation is independent from possible asymmetries of the communications channel (different forward and reverse times).

1.1.2 Directional Comparison Units

DLX relays incorporate Phase, Ground, Positive Sequence and Negative Sequence Directional Comparison Elements to support the Differential Elements, providing, with no need for reducing their sensitivity, a great security on external faults with CT saturation.

Directional Comparison Elements, operating on the phase difference between the currents measured at both line ends do not require practically any setting.

1.1.3 Phase and Ground Overcurrent Protection (3x50/51 + 50N/51N)

Depending on the model, there are four Overcurrent Measuring Units (three Phase and one Ground unit). Each unit contains three time and three instantaneous elements with an additional adjustable timer.

The Time Units have a wide range of selectable time-current curves according to IEC and IEEE/ANSI standards: Fixed Time, Moderately Inverse, Inverse, Very Inverse, Extremely Inverse, Long-Time Inverse, Short-Time Inverse, RI Inverse, as well as any of them configured with a Time Limit, and one User-Defined Curve.

When Time Elements have been configured to operate in accordance with an inverse curve, one can select whether this should be instantaneously reset when values registered fall below a specific threshold, or in accordance with an emulation of the disc for electromechanical relays.

These models have independent LED targets for each element for the pickup and trip of the phase and neutral time and instantaneous units. They can be directed to any logic signal.

1.1.4 Sensitive Ground Overcurrent Protection (50Ns/51Ns)

Depending on the model, there is also one Sensitive Ground metering unit made up of a time element and an instantaneous element with an additional adjustable timer. The characteristics of the time unit are identical to those indicated in the preceding case.

1.1.5 Negative Sequence Overcurrent Protection (50Q/51Q)

All the models have Negative Sequence Overcurrent measuring units. These units are made up of three time and three instantaneous elements with an additional adjustable timer.

1.1.6 Directional Units (3x67 + 67N + 67Q + 67Ns) (DLX-B Models)

For **DLX-B** Models it is possible to set any of the previously mentioned Overcurrent units as directional units:

- **Phase Directional Units**. One directional element is associated with each phase. Polarization is done by between-phase voltage with memory.
- **Ground Directional Unit**. Includes double polarization: by ground voltage and by grounding current.
- **Negative Sequence Directional Unit**. Polarized by negative sequence voltage.

1.1.7 Ground Overcurrent Protection Schemes (85-67N/67Q) (DLX-B Models)

DLX-B Model Ground and Negative Sequence Directional Overcurrent elements can be provided with the following Protection Schemes.

- Permissive Underreach Trip.
- Direct Transfer Trip.
- Permissive Overreach Trip.
- Directional Comparison Unblocking.
- Directional Comparison Blocking.

Apart from the Protection Schemes available, any other protection scheme can be configured, through the equipment programmable logic.

- **Permissive Underreach Tripping**

The operation of this scheme is based on the fact that if one terminal sees the fault in underreach unit (adjusted below 100% of line) and the other terminal sees the fault in the overreach zone (adjusted above 100% of line), then the fault can be considered as internal.

By activating the underreach unit, a local end instantaneous trip is generated and a permissive trip signal is sent to the remote end so as to speed up the tripping. The remote terminal will trip instantaneously upon receiving the permissive trip signal and if some unit in the overreach zone is picked up.

- **Direct Transfer Tripping**

This scheme is similar to the Permissive Underreach Tripping, except that upon receiving the trip signal form the other end, an instantaneous trip is generated with no additional supervision.

- **Permissive Overreach Tripping**

This scheme is based on the fact that if both terminals see the fault in the overreach zone (adjusted above 100% of the line, overreaching), the fault can be considered as internal to the line.

The permissive trip signal is sent by the activation of overreach zone. Reception of said signal by the remote end generates an instantaneous trip only if the overreach zone at this end is picked up.

- **Directional Comparison Unblocking**

This scheme is an extension of the Permissive Overreach Tripping Scheme, which allows for instantaneous tripping of faults internal to the line when no permissive trip signal is received from the other end. It is mainly used as a permissive scheme when using carrier wave communications, so as to avoid delayed tripping on losing the trip signal as a consequence of the large attenuation caused by the fault.

- **Directional Comparison Blocking**

This scheme basically differs from the two previous schemes in that the signal sent through the channel is used to block the tripping of the remote end, instead of speeding it up. The blocking signal will be generated by the pickup of a reverse looking element, which will indicate that the fault is behind, in the adjacent line.

Apart from the protection schemes available, there exists the possibility to configure any other scheme via the relay programmable logic.

Overcurrent elements designated as underreach and overreach can be set to produce single phase trips thanks to the phase selector of the relay.

- **Additional Logics for Distance Protection Schemes**

These logics, if enabled, can work in parallel with all the permissive schemes.

Weak Infeed Logic (27WI)

- **Echo Logic**: the echo function allows one end under a weak infeed condition to send back a permissive trip signal received from the other end in order to speed up the tripping from the “strong” end.
- **Tripping Logic**: said logic, which will operate together with the echo function, allows for instantaneous tripping of the weak end based on undervoltage conditions.

Reverse Current Blocking Logic

This logic prevents the overreach zone from generating wrong trips on current reversals occurring during sequential trips from a fault in a line parallel to the protected line. The overreach zone is only blocked, for an adjustable time, when a fault is detected in the parallel line.

1.1.8 Undervoltage Units (3x27) (DLX-B Models)

There are three Overvoltage Units (three phases) independently selectable as Line or Phase voltage for models with voltage analog inputs. Each consists of three instantaneous elements with an additional adjustable timer. You can set the trip of each unit as single-phase or three-phase overvoltage. There are status contact inputs for blocking minimum voltage trip.

1.1.9 Overvoltage Units (3x59) (DLX-B Models)

There are three Overvoltage Units (three phases) independently selectable as Line or Phase voltage for models with voltage analog inputs. Each consists of three instantaneous elements with an additional adjustable timer. You can set the trip of each unit as single-phase or three-phase overvoltage. There are status contact inputs for blocking maximum voltage trip.

1.1.10 Ground Overvoltage Unit (1x59N) (DLX-B Models)

All models are provided with two residual overvoltage metering elements. They take the measurement obtained by calculating the three phase voltages available in the IED. Said metering units are composed of two instantaneous elements with additional adjustable timer. There are status contact inputs for blocking ground overvoltage trip.

1.1.11 Underfrequency (81m), Overfrequency (81M) and Rate of Change (81D) Protection (DLX-B Models)

The models with analog voltage inputs have an analog voltage input for obtaining the frequency and nine metering units (3 Underfrequency, 3 Overfrequency and 3 Frequency Rate of Change). Each of these units contains one element with an adjustable timer. You can set it as instantaneous.

There are status contact inputs for blocking trips induced by any of these frequency units.

1.1.12 Dead-Line Detector (DLX-B Models)

The **DLX-B** relay incorporates a Dead-Line detection element, which allows detecting deenergized lines based on the operation of two elements, undercurrent and undervoltage. The Dead-Line Detector allows detecting the closing of the breaker (one line energized), so that can be used by the Differential Units with the benefit of not requiring external contacts.

1.1.13 Breaker Failure (50/62BF)

The **DLX** incorporates Breaker Failure protection with two time steps so that retripping (single or three-phase) of failed breaker can be produced, if required, prior to the tripping command of adjacent breakers.

Breaker Failure protection incorporates separate timers and overcurrent levels for single-phase and three-phase tripping. Pickups generated by single-phase tripping incorporate overcurrent detectors and phase segregated timers in order to act correctly in the event of evolving faults. All overcurrent detectors have very fast resetting characteristics.

Also, this unit allows protection against breaker failure with no overcurrent and detects the presence of active internal arcing.

1.1.14 Open Pole and Pole Discordance Detector (2)

The equipment incorporates Open Pole detection logic, which operates based on the position of the breaker contacts this being backed up by phase segregated current detectors. Said logic output is taken into account for the operation of a number of protection devices, due to various conditions generated by an open pole.

On the other hand, the equipment allows for the detection of breaker pole discordance condition, which could cause a trip if the condition remains unchanged for an adjustable time.

1.1.15 Open Phase Unit (46)

All the models have an Open Phase unit to detect the opening or unbalance of one or more phases. When this is detected, the unit trips and eliminates the unbalance. It operates on a time characteristic with a fixed time adjustable timer.

1.1.16 Synchronism Unit (25) (DLX-B Models)

In models with voltage analog inputs there is a Synchronism Check Unit that checks various values, such as the existence of voltage in buses and line and the magnitude, angle and frequency difference between the two so that the breaker can reset (internal synchronism).

Each criterion of the four mentioned can be disabled separately. The existence of synchronism for any of the possible criteria is also indicated separately. Moreover, it can be directed to the IED’s configurable logic.

You can also check external synchronism. You only need to activate an external digital input of synchronism to allow the reset.

The synchronism unit can supervise both the manual resets as well as the resets given by the Recloser function.

1.1.17 Thermal Image Unit (49)

The IED has a Thermal Image unit that uses the current circulating through the wires to estimate their thermal status in order to trigger a trip when they have reached high temperatures.

This module is prepared to protect lines, motors and transformers from overheating according to the setting available for that purpose in the IED. You can also enable or disable it with another setting in the IED.

The unit provides an alarm or a trip independently. You can direct both to the IED’s configurable logic.

1.1.18 Cold-Load Pick-Up

All models are provided with a Cold-Load Pick-Up unit. The purpose of this function is to avoid trips when reconnecting heavy loads. This is achieved by temporarily selecting a different settings group.

1.1.19 Recloser (DLX-A Models) (79)

The recloser can be coordinated with external protection as well as with the protection contained in the IED.

A maximum of three attempts can selected, with independent settings for reclosing times. The reclosing sequence is controlled by the breaker position and by the reclose initiate signal.

The reclosing sequence after Zone 1, 2, 3 and 4 tripping; and after overcurrent, open phase and remote open breaker units tripping will be determined according to the settings.

1.1.20 Single / Three-Phase Recloser (DLX-B Models) (79)

Apart from the above described points, the **DLX-B** recloser features separate cycles for different tripping modes: single and three-phase, and the following operation modes can be selected:

- **1p Mode**: Reclosing for single-phase trips only.
- **3p Mode**: Reclosing for three-phase trips only.
- **1p/3p Mode**: Reclosing for both types of trips.
- **Dependent Mode**: Only one reclosing attempt for three-phase tripping, and as programmed by the number of reclosing attempts setting for single-phase tripping.

1.1.21 Current measurement supervision (60CT)

All models have a system for the supervision of the set of elements that make up the system for measuring phase currents, ranging from external current transformers to the copper cables that connect elements to the relay, to internal magnetic modules for the **DLX** equipment.

1.1.22 Fuse Failure Detector (60VT)

Models with analog voltage inputs have a Fuse Failure Detector that can block the operation of the elements based on voltage measurements (phase undervoltage and overvoltage, ground overvoltage, synchronism, etc.) if any of the voltages in the secondary voltage transformer disappear.

All the protection functions described have 4 selectable setting groups (one active and three alternative groups) for their corresponding rating under various system conditions. Each function can be enabled or disabled during configuration or by commands transmitted via the communications ports, operator interface (HMI) or digital inputs.

They all have independent LED targets for each element (to which the phase distinction is applied) for the pickup and trip of the phase and ground time and instantaneous elements. They can be directed to any logic signal.

1.2 Additional Functions

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1.2.1 Local Control

You have programmable and function buttons on the front of the IED for operating on the system's configurable elements in the IED (Breaker, Sectionalizers, Recloser Function, Automatic Control Functions, Protection Units, Local/Remote, Active Group of Settings, etc.) and for resetting the operation LEDs.

1.2.2 Programmable Logic

An operational logic can be programmed in order to set up blockings, automatic controls, control and trip logic functions, command hierarchy, etc through logic gates combined with any captured or equipment-calculated signal.

All the signals generated by the equipment will be available to the events, fault reports, oscillograph records, digital inputs and outputs, HMI and communications according to how their programmable logic has been configured.

The processing of the input signals produces logical outputs that can be assigned to existing connections between the **DLX** and the exterior: auxiliary output contacts, display, communications, LEDs, HMI…

1.2.3 Ports and Communications Protocols

Apart from the communications ports required by the Differential function, **DLX** relays are provided with other ports to carry out protection management and control functions:

- **1** front **Local Port** type RS232C and USB.
- Up to **3 Remote** fiber optic ports (ST Glass or 1mm plastic), electrical interface RS232/RS485, or LAN on connector RJ45 for ETHERNET-type communications. One of these remote ports can be used for BUS connection with CAN protocol.

The IED also has the following communications protocols: PROCOME 3.0, DNP 3.0, MODBUS (you can assign any one of them to both remote ports) and CAN (electric BUS CAN). The local port supports the PROCOME 3.0 Protocol. It is for parameter setting, configuration and retrieval of information about the IED.

Protocol changeover trailers are totally independent for each port and same-protocol instances can be maintained in all of the remote ports.

1.2.4 Integrated Simulator

The equipment count on a special mode for testing and simulating the operation of implemented units by means of loading an external oscillogram into the device through the front communication port.

1.2.5 Trip and Close Coil Circuit Supervision

The IED has units for verifying the proper operation of the switching circuits of the breaker. They can monitor up to three coils. You can monitor both breaker positions (open and closed) or either one of them.

1.2.6 Selecting the Phase Sequence

You can configure the connection of the IED to the network sequence when the phase sequences are ABC or ACB.

1.2.7 Number of Voltage Transformers (DLX-B Models)

You can configure the IED to measure voltages with three transformers that measure phase-ground voltages or two that measure phase-phase voltages (UAB and UBC). In either case, the relay remains totally functional.

1.2.8 Breaker Monitoring

To have information for maintaining the breaker, the IED has a unit that sums and accumulates the kA^2s values each time it trips.

1.2.9 Excessive Number of Trips

This function prevents the breaker from making an undesirable number of operations in a given period of time, which may result in breaker damage. When the maximum number of trips allowed is surpassed, the Recloser function is blocked.

1.2.10 LED Targets

There are eight configurable LEDs and additional one indicating equipment “Ready” on the equipment.

1.2.11 Digital Inputs

The number of digital inputs available will depend on each particular model (see 1.4, Model Selection). These can range from 8 to 18.

1.2.12 Auxiliary Outputs

The number of auxiliary outputs available will also depend on each particular model (see 1.4, Model Selection) and may vary from 3 up to 8. One of these outputs is not configurable as it is assigned to the relay “Ready” indication.

1.2.13 Time Synchronization

The IEDs include an internal clock with a resolution of 1 ms. This can be synchronized via GPS (IRIG-B 003 and 123 Protocol) or by communications through remote communications port (PROCOME 3.0 or DNP 3.0 Protocols).

Differential element synchronization by GPS has an accuracy of 25 μs. In this case the use of a digital rather than analog IRIG-B signal is recommended.

1.2.14 Fault Locator (DLX-B Models)

DLX-B relays incorporate two Fault Locators, one based only on local measurements and the other using local and remote measurements. This latter locator, which will get more accurate results than the first locator, will operate if the remote measurements are available at the time of tripping. Otherwise, the distance to the fault will be calculated by the locator based only on local data.

The distance to the fault will be given in kilometers, in miles or in percentage of the total length of the line.

1.2.15 Event Recording and Programmable Metering Data Logging

Storage capacity of 400 annotations in a non-volatile memory. Event-generated signals can be selected by the user and are annotated with 1ms resolution and a maximum of 12 measurements also user-selected.

1.2.16 Fault Reporting

Storage capacity of up to 15 fault reports with relevant information, such as units picked up, units tripped, pre-fault values, fault values, current interrupted by breaker, etc.

1.2.17 Historical Metering Data Logging

Historical metering data logging allows for obtaining twelve maximum and twelve minimum values from a group of four magnitudes selected out of all available measurements (captured or calculated), except meters, for each time window. This window can be adapted to the application by adjustment of day and interval masks. Up to 168 records can be saved.

1.2.18 Oscillographic Register

The Oscillographic Recording function is composed of two different sub functions: capture and display. Both analog magnitudes and internal signals as well as digital equipment inputs will be recorded, up to a total of 64 oscillograms in a circular memory. Sampling and storing frequency is 32 samples per cycle with 15 seconds of total storage. Oscillograms are delivered in format COMTRADE 99.

A program for the display and analysis of the captured oscillograms is supplied with the equipment.

1.2.19 Alphanumeric Display and Keypad

- Changing and displaying settings.
- Protection operations:
  - Last trip and Recloser status.
  - Units picked up.
  - Tripped units.
  - Contact input and output status.
  - Distance to the fault.
- Protection records (displayed via communication):
  - Event recording.
  - Fault report.
  - Log file of currents, voltages, powers, power factor and energies or other calculated values.
- Control records.
- Metering values used by protection:
  - Phase and ground currents and their angles
  - Voltages of the three phases and ground and their angles
  - Synchronism voltage
  - Phase-to-phase voltages
  - Local and remote phase, ground and negative sequence currents.
  - Local and remote positive sequence voltages.
  - Phase, ground and negative sequence differential currents.
  - Phase, ground and negative sequence restraint currents.
  - Thermal image value
  - Maximum and minimum current
  - Maximum and minimum voltage
  - Positive, negative and zero sequence currents and their angles
  - Positive, negative and zero sequence voltages and their angles
  - Active, reactive and apparent powers and power factor
  - Maximum and minimum powers
  - Frequency
  - Energies
  - 2nd to 8th order harmonics of the current and voltage of phase A.
  - Times calculated by the differential element synchronization algorithm.

1.2.20 Self-Test Program

A continuously running diagnostic self-test program verifies the correct operation of the terminal unit and alerts the user of potential problems.

1.3 Local Interface: Alphanumeric Display and Keypad

1.3.1	Alphanumeric Display and Keypad	1.3-2
1.3.2	Control Buttons	1.3-2
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1.3.4	Last Trip Indication	1.3-6

1.3.1 Alphanumeric Display and Keypad

The resolution of the display is 320 pixels horizontally, and 240 vertically and it has a depth of colour consisting on 16 bits = 65536 colours. You can visualize alarms, settings, measurements, status, etc. from the display. Next to the display is the keypad. The next section explains the functions associated to these keys. Figure 1.3.1 represents the layout of the default display.

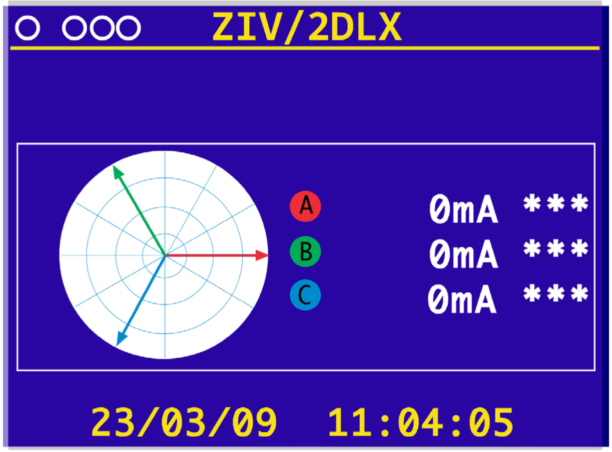


Figure 1.3.1 Alphanumeric Display.

- **Default Display**

As shown under Figure 1.3.1, the default display presents the model in question, the date and time, and the measurement of phase voltages and currents with their respective angles can be visualized in the same. The left-hand side of the top line also describes that communication has been established with a green light.

- **Keypad associated to the Alphanumeric Display**

The keypad has 4 keys, as follows:

▲ This key provides access to a display where events are visualized.

▶ This key enables you to visualize measurements.

▼ This key provides access to digital inputs and outputs.

◀ This key enables access to a display where faults are visualized.

The keypad also provides an **Enter** key ↵ (in the centre) and an **Escape** key (**ESC**).

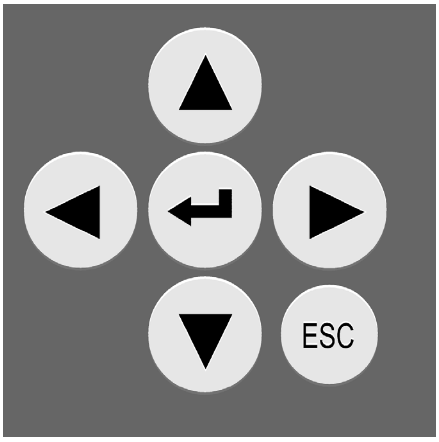


Figure 1.3.2 Keypad.

1.3.2 Control Buttons

Three buttons are available to operate the system elements, setting tables or protection units configured in the unit: buttons **I** and **O** (closing and open controls, respectively) and button **79** for reclosing.

Figure 1.3.3 Control Buttons.

It must be taken into account that control buttons corresponding to open and closure are associated by default to 1 and 0 ◄ ►, hence, in principle, these could not be used for programmable logic, unless through the ***Ziverlog***® program, and under the section **Configuration of the Front Panel's Control Buttons**, this provides the option of disassociating the buttons and, thus, be able to use them for the logic, as displayed under figure 1.3.4.

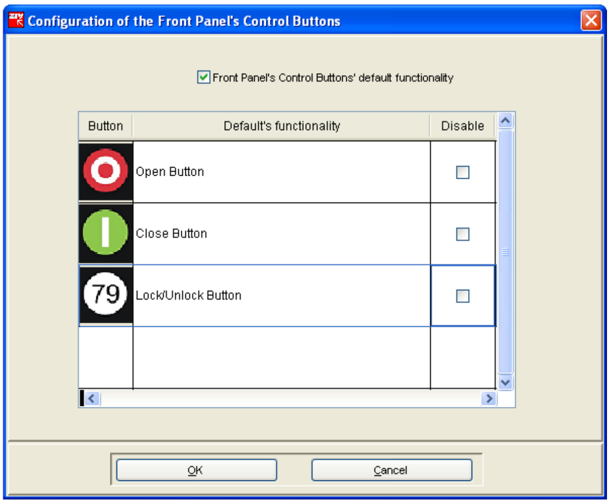


Figure 1.3.4 Configuration of Control Buttons.

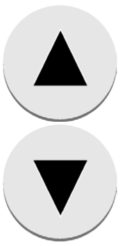
1.3.3 Keys, Functions and Operation Modes

The following is a description of the functions provided by available keys, both as regards the functions associated to the alphanumeric display and those of the keypad.

1.3.3.a Keypad

Confirmation key
The confirmation key is used for confirming an action: after making a selection, or after editing a setting, or else to go on to visualize the totality of the registered data. After an operation is carried out (selection, change of settings, information, etc), press ← again and return to the immediately previous level.

Escape key
The ESC key is used to exit the display if you do not wish to make any modification in the setting, or if you simply wish to exit the information display. In any case, when you press this key the system returns to the immediately previous level.



Selection keys on the display
You can go forward or backward in correlative order, using the selection keys, to any of the options available in a menu or submenu. When more than eight options are available in a menu, an arrow (⇓) will be visualized on the right-hand side of the display, indicating the existence of the same. These options will be accessed with key ▼ and the options that appear in the first place will cease to be visualized,

Then, a bar with an arrow (⇑) will appear on the right-hand side of the display, which will indicate, at the same time, the existence of these first options.

The key ◄ is also used for erasing digits within a setting when modifications are being carried out on the same. It only has this function when the setting is being introduced.

1.3.3.b Auxiliary Function Keys

When this key is pressed from the default display, it gives access to the information provided by the registration of control changes.

The key ► is used for consulting the unit as regards the data pertaining to current, voltage, power, etc. measurements, and to reset the last trip indication and the LEDs.

The function key ► is used for rejecting the changes undertaken on the settings (when the unit requests the confirmation of these changes) and to reject the activation of a table of reserve settings (also when this confirmation is requested).

By pressing ▼ you can visualize the status of digital inputs and outputs from the unit.

Once the status of digital inputs is on screen, click the function key ► to visualize the status of digital outputs.

By pressing ◄ you confirm the changes of settings undertaken (when the unit requests that changes need to be confirmed) or the activation of a table of settings is confirmed (when the unit requests that changes need to be confirmed).

1.3.3.c Access to Options

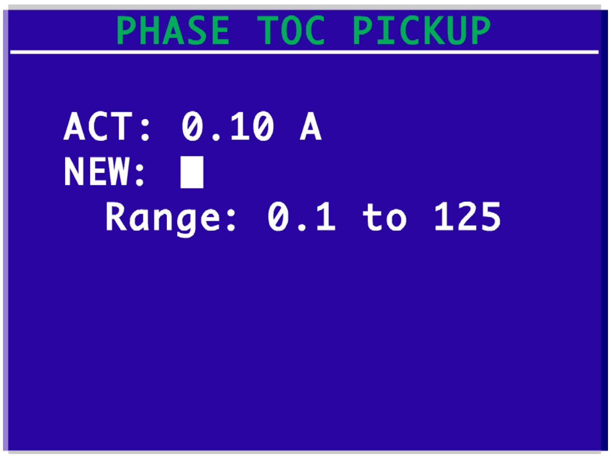
To access options, you must scroll around the menus using the selection keys and afterwards confirm the option selected by pressing **ENT**.

1.3.3.d Operation

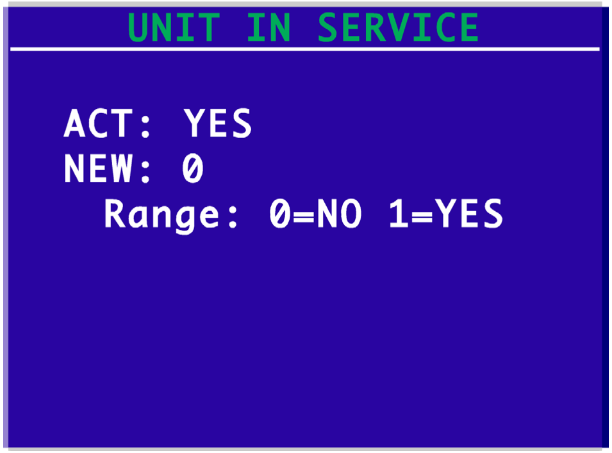
- **Range Settings**

Range settings are displayed as follows: the operational value of the setting is displayed under **ACT** (Actual). The new value is introduced in the next line, under **NEW**, where the cursor will display an intermittent flash.

The new function keys are used for editing the new value which must tally with the range specified in the last line of the display. If there is an error when a value is introduced, you must use key ◄ to erase the same. Once the new value has been edited, press key ↩ to confirm the same and exit to the previous menu.

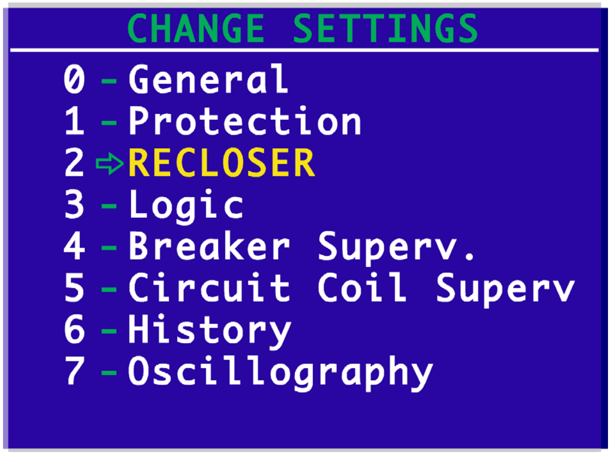


There is a type of setting that adjusts to this scheme, but its range is limited to options **YES** and **NO**. Keys ◄ (1) and ► (0) correspond in this case to values **YES** and **NO**. After this, press key ↵ to confirm the setting and return to the previous screen.



- **Settings for the Selection of an Option**

These settings present the layout of an options menu. Select the required option through the selection keys and confirmation using ↵. Thus, the system returns to the previous screen.

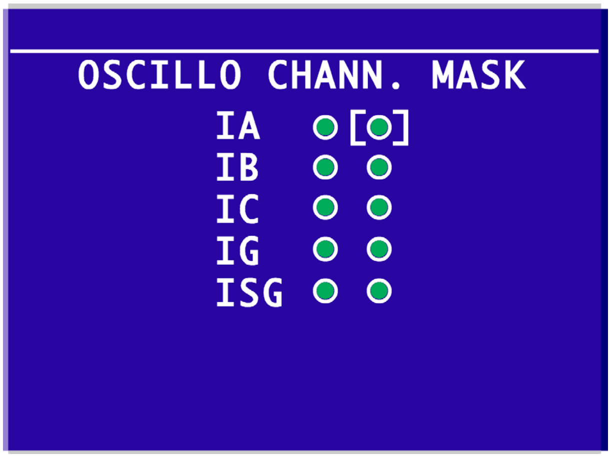


- **Masks Settings**

As can be observed from the screen, the different options are presented in vertical order. Its current setting is: an empty circle or a filled circle which indicates enabled (●) or disabled (○) respectively.

The mask is modified (in the line indicated by brackets) using keys ◄ (1), enable, and ► (0), disabled.

In the event that there are more options than those that can represented in one screen alone, an arrow (↓) will appear at the end of the last line, which will indicate the existence of that second screen. This second screen appears as soon as the last option on the first screen has been set.



- **Exit Menus and Settings**

In order to exit a menu or setting that you do not wish to modify, press **ESC** key. To exit a data display, you can either press the confirmation key ↵ or **ESC**. In all cases, you will return to the previous menu.

1.3.4 Last Trip Indication

If any trip has taken place, the terminal would display, in the first place, data regarding the same. This data would be visualized as follows:

Additional screens will be created depending on the last types of units that trip. The format is always similar: a heading line that indicates the type of unit that has tripped (for example, Temp Current), and below this, all the elements and phases that have been involved (Temp1 A, Temp1 B,...). If various functions should trip, and thus do not all fit into one screen, you can access all the functions involved through the selection keys.

If, on the contrary, no trips have taken place since the last reset, this screen will not be displayed.

1.4 Model Selection

1.4.1 Model Selection... 1.4-2

1.4.1 Model Selection

DLX											
1	2	3	4	5	6	7	8	9	10	11	12

2	**Functions**			
	A	3x87 + 87N + 87Q + 3x87P + 87PP + 87PN + 87PQ + 3x50/51 + 50N/51N + 50Ns/51Ns + 50Q/51Q + 79 + 49 + 50BF + 46 + 60CT + 50SOF + 3x3+2	**B**	3x87 + 87N + 87Q + 3x87P + 87PP + 87PN + 87PQ + 3x50/51 + 50/51N + 50Ns/51Ns + 50Q/51Q + 3x67 + 67N + 67Ns + 67Q + 3x27 + 3x59 + 1x59N + 81M/m + 81D + 79(1P/3P) + 25 + 49 + 50BF + 46 + 60CT + 60VT + FL+ DL(Dead Line) + 27WI + Teleprotection Schemes
3	**Options**			
	1	Standard Model		
4	**Hardware Options**			
	N	Standard Model	**S**	Integrated Simulator
	R	Long term oscillographic register (20OSC x 10s)		
5	**Power Supply Voltage**			
	1	24 Vdc (±20%) / 24 Vac (±10%)	**2**	48 - 250 Vdc (±20%) / 48 - 230 Vac (±10%)
6	**Digital Inputs**			
	0	24 Vdc	**2**	125 Vdc
	1	48 Vdc	**3**	250 Vdc
7	**Communications Ports [COM1-LOC] [COM 2-REMP1] [COM3-REMP2] [COM4-REMP3]**			
	0	[RS232+USB] [--] [--] [--]	**7**	[RS232] [GFO ST] [GFO ST] [--]
	1	[RS232] [ETHERNET] [RS232 / RS485] [--]	**8**	[RS232] [GFO ST] [RS232 / RS485]
	2	[RS232+USB] [ETHERNET] [RS232 / RS485] [--]	**9**	[RS232] [PFO] [PFO] [--]
	3	[RS232+USB] [GFO ST] [GFO ST] [--]	**A**	[RS232] [PFO] [RS232 / RS485] [--]
	4	[RS232+USB] [GFO ST] [RS232 / RS485] [--]	**B**	[RS232] [RS232 / RS485] [RS232 / RS485] [--]
	5	[RS232+USB] [PFO] [GFO] [--]	**C**	[RS232+USB] [RS232 / RS485] [RS232/ RS485] [--]
	6	[RS232+USB] [PFO] [RS232 / RS485] [--]		
8	**Inputs / Outputs**			
	0	8DI + 2DO + 1 TRIP + 1 CLOSE + 1DO In Service	**2**	18DI + 7DO + 1 TRIP + 1 CLOSE + 1DO In Service + 1 TI. Sup. VDC (0-300Vcc)
	1	18DI + 7DO + 1 TRIP + 1 CLOSE + 1DO In Service + 1 TI. (1)	**3**	18DI + 5DO + 3 TRIP + 1 CLOSE + 1DO In Service + 1 TI. (1) (Only B Model)
			4	18DI + 5DO + 3 TRIP + 1 CLOSE + 1DO In Service + 1 TI.Sup. VDC (0-300Vcc) (Only B Model)
9	**Spare (to be defined in the factory)**			
	00	Standard Model		
10	**Enclosure**			
	G	4U x 19" 1/2 Rack (DI / DO type 0 and 1)		
11	**Communications Protocols [COM1-LOC] [COM 2-REMP1 + COM3-REMP2] [COM4-REMP3]**			
	B	[PROCOME 3.0] [-] [-]	**L**	[PROCOME 3.0] [PROCOME 3.0/DNP 3.0 (Profile II)/MODBUS(2)]. SERIAL, ETHERNET [PROCOME 3.0/DNP 3.0 (Profile II)/MODBUS (2)]. SERIAL, ETHERNET
	K	[PROCOME 3.0] [PROCOME 3.0/DNP 3.0 (Profile II)/MODBUS (2)] [PROCOME 3.0/DNP 3.0 (Profile II)/MODBUS (2)]		
12	**Finishing**			
	--	Printed Circuit Board No Tropicalized + Standard Colors [**O** – Red and **I** - Green]	**Q**	Printed Circuit Board Tropicalized + Changed Colors [**O** – Red and **I** - Green]
	L	Printed Circuit Board Tropicalized + Standard Colors [**O** – Red and **I** - Green]		

1. Selectable (0-5)mA or (±2.5)mA
2. Selectable independently for COM2 and COM3
3. Selectable only for DLX-B models

- **Functions**

50	Phase Instantaneous Overcurrent
51	Phase Time Overcurrent (inverse / definite)
50N	Ground Instantaneous Overcurrent
51N	Ground Time Overcurrent (inverse / definite)
50Ns	Sensitive Ground Instantaneous Overcurrent
51Ns	Sensitive Ground Time Overcurrent (inverse / definite)
50Q	Negative Sequence Instantaneous Overcurrent (I2)
51Q	Negative Sequence Time Overcurrent (inverse / definite) (I2)
67	Phase Directional
67N	Ground Directional
67Ns	Sensitive Ground Directional
67Na	Ungrounded Neutral Directional
67Q	Negative Sequence Directional
51V	Voltage Dependent Phase Overcurrent
27	Phase Undervoltage
59	Phase Overvoltage
59N/64	Ground Overvoltage
47	Negative Sequence Overvoltage
81M	Overfrequency
81m	Underfrequency
81D	Frequency Rate of Change
50/62BF	Breaker failure
46	Open Phase
61	Residual Current Detection
25	Synchronism Check
78	Out-of-Step
49	Thermal Image
32P/Q	Directional Power
37	Phase Undercurrent
87N	Restricted Earth Faults
79	Recloser
60CT	Current measurement supervision
60VT	Fuse Failure Detector

1.5 Installation and Commissioning

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1.5.5	Tests	1.5-4
1.5.5.a	Isolation Test	1.5-4
1.5.5.b	Power Supply Test	1.5-5
1.5.5.c	Metering Tests	1.5-5

1.5.1 General

Improper handling of electrical equipment is extremely dangerous, therefore, only skilled and qualified personnel familiar with appropriate safety procedures and precautions should work with this equipment. Damage to equipment and injury to personnel can result when proper safety precautions are not followed. The following general safety precautions are provided as a reminder:

- **High magnitude voltages are present in Power Supply and metering circuits even after equipment has been disconnected.**
- **Equipment should be solidly grounded before handling or operating.**
- **Under no circumstances should the operating limits of the equipment be exceeded (voltage, current, etc.).**
- **The power supply voltage should be disconnected from the equipment before extracting or inserting any module; otherwise damage may result.**

The tests defined next are those indicated for the start-up of an IED. They do not necessarily coincide with the final manufacturing tests to which each manufactured IED is subjected. The number, the type and the specific characteristics of the acceptance tests are model dependent.

1.5.2 Accuracy

The accuracy of the measuring instruments and test source signals (auxiliary power supply voltage, AC currents and AC voltages) is key in electrical testing. Therefore, the information specified in the Technical Data section (2.1) of this manual can only be reasonably verified with test equipment under normal reference conditions and with the tolerances indicated in the UNE 21-136 and IEC 255 standards in addition to using precision instruments.

It is extremely important that there be little or no distortion (<2%) in the test source signals as harmonics can affect internal measuring of the equipment. For example, distortions will affect this IED, made up of non-linear elements, differently from an AC ammeter, because the measurement is made differently in both cases.

It must be emphasized that the accuracy of the test will depend on the instruments used for measuring as well as the source signals used. Therefore, tests performed with secondary equipment should focus on operation verification and not on measuring accuracy.

1.5.3 Installation

- **Location**

The place where the equipment is installed must fulfill some minimum requirements, not only to guarantee correct operation and the maximum duration of useful life, but also to facilitate placing the unit in service and performing necessary maintenance. These minimum requirements are the following:

- Absence of dust.
- Absence of humidity.
- Absence of vibration.
- Good lighting.
- Easy access.
- Horizontal or vertical mounting.

Installation should be accomplished in accordance with the dimension diagrams.

- **Connections**

The first terminal of the terminal block corresponding to the auxiliary power supply must be connected to ground so that the filter circuits can operate. The cable used for this connection should be 14 AWG stranded wire, with a minimum cross section of 2.5 mm^2. The length of the connection to ground should be as short as possible, but not more than 75 inches (30 cm). In addition, the ground terminal of the case, located on the rear of the unit, should be connected to ground.

1.5.4 Preliminary Inspection

The following equipment aspects should be examined:

- The unit is in good physical condition, mechanical parts are securely attached and no assembly screws are missing.
- The unit model number and specifications agree with the equipment order.

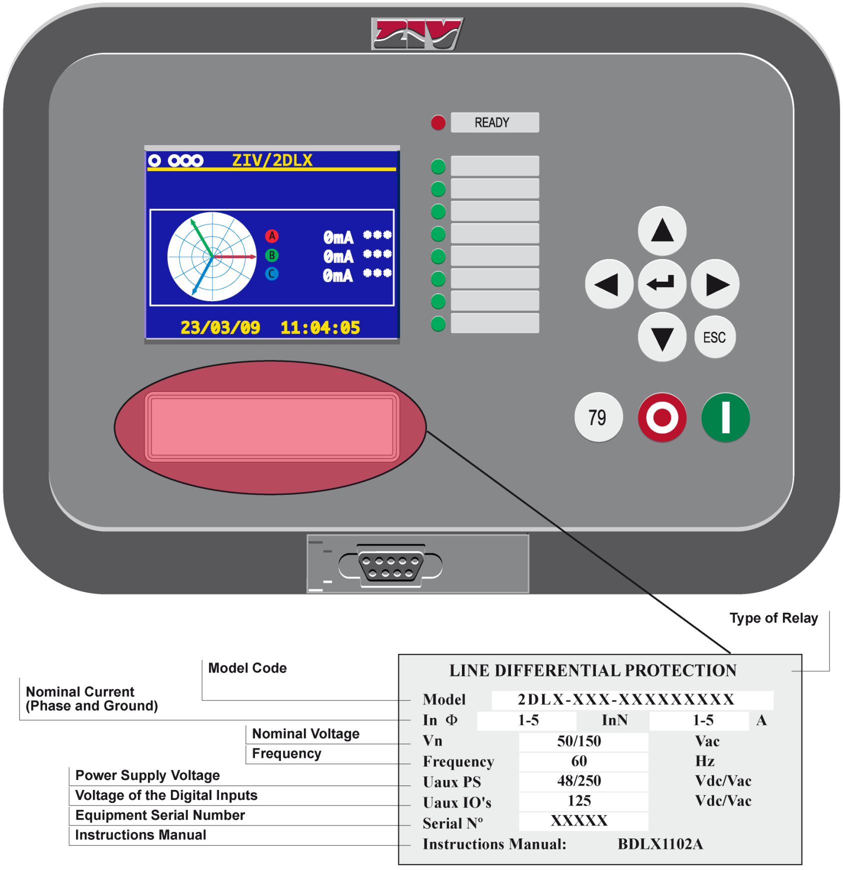

Figure 1.5.1 Name Plate (2DLX).

1.5.5 Tests

1.5.5.a Isolation Test

While testing for isolation of switchgear and external wiring, the IED must be disconnected to avoid damage in case the test is not performed properly or if there are shorts in the harness, since the manufacturer has performed isolation testing on 100% of the units.

- **Common Mode**

All the terminals of the IED must be short-circuited, except those that relate to the power supply. The enclosure ground terminal must also be disconnected. Then 2000 Vac are applied between the interconnected terminals and the metal case for 1 min or 2500 Vac during 1s between the terminal group and the metal enclosure. When the IED has the inputs, outputs and converters expansion card, terminals of the transducers do not need to be short-circuited (See External Connection Schemes).

- **Between groups**

The isolation groups are made up of the current and voltage inputs (independent channels), digital inputs, auxiliary outputs, trip and close contacts and power supply. Refer to the connection's schematic to identify the terminals to group for performing the test. Then 2500 VAC are applied during 1 sec. between each pair of groups. For the transducers test 1,000 VAC are applied during one second between this group and all the rest.

WARNING!

There are internal capacitors that can generate high voltage if the test points are removed for the insulation test without reducing the test voltage.

1.5.5.b Power Supply Test

Connect the power supply as indicated in following table.

VDC PROT	CON1P	CON2P
C22(+) - C23(-)	C9-C10	C9-C11

It is important to verify that, when the IED is not energized, the contacts designated CON2P in the table mentioned previously are closed, and those designated CON1P are open. Then it is fed its rated voltage and the contacts designated CON1P and CON2P must change state and the “Ready” LED must light up.

1.5.5.c Metering Tests

For this test it should be considered that, if it is required to avoid trips while this is being carried out, the elements should be disabled and the cutoff of the injection of current and/or voltage by the breaker avoided. Subsequently, the currents and voltages which, as an example, are indicated in the following table, will be applied to each of the channels and the following measures will be verified:

Applied Current or Voltage	Measured Current or Voltage	Phase of I or V applied	Phase of I or V measured	Freq. Applied (V > 20 Vac)	Freq. Measured (V > 20 Vac)
X	X ±1%	Y	Y ±1°	Z	Z ±5 mHz

Note: to check high current values, they are applied during the shortest possible time; for example, for 20 A, less than 8 seconds. To be able to view the angles, the phase A voltage must be applied the same as for measuring the frequency.

Chapter 2.

Technical Specifications and Physical Description

2.1 Technical Data

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2.1.17 Communications Link 2.1-8

2.1.1 Power Supply Voltage

IEDs have two types of auxiliary power supplies. Depending on the model, their values are selectable:

48 - 250 Vdc/Vac (±20%)
24 Vdc (±20%) / 24 Vac (±10%)

Note: In case of power supply failure, a maximum interruption of 100 ms is allowed for 110 Vdc input.

2.1.2 Power Supply Burden

Quiescent	**7 W**
Maximum	**<12 W**

2.1.3 Current Analog Inputs

Phase, Ground and Polarization Currents

Nominal Value	**In** = **5 A** or **1 A** (Selectable in the IED)
Thermal withstand capability	**20 A** (continuously) **250 A** (for 3 s) **500 A** (for 1 s)
Dynamic limit	**1250 A**
Current circuit burden	**<0.2 VA** (**In** = **5 A** or **1 A**)

Sensitive Ground Currents

Nominal Value	**In** = **20 mA**
Thermal withstand capability	**5 A** (continuously) **62.5 A** (for 3 s) **125 A** (for 1 s)
Dynamic limit	**300 A**
Current circuit burden	<0.05 VA (In = 1 A or 20 mA)

2.1.4 Voltage Analog Inputs

Nominal Value	**Un** = **50** to **230 Vac** (selectable in the IED)
Thermal withstand capability	**300 Vac** (continuously) **600 Vac** (for 10s)
Voltage circuit burden	**0.55 VA** (110/120 Vac)

2.1.5 Frequency

Operating range	**40 - 70 Hz**

2.1.6 Measurement Accuracy

Measured currents	**±0.1%** or **±2 mA** (the greater)
Phase and Ground	for In = 1A and 5A
Measured currents	
Sensitive Ground	**±0.1%** or **±0.5 mA** (the greater)
Calculated currents	
Phase - Phase	**±0.2%** or **±6 mA** (the greater)
I_1, I_2 and I_0	**±0.3%** or **±8 mA** (the greater)
	for In = 1A and 5A
Differential and Restraint Currents	**±0.5%** or **±10 mA** (the greater)
Measured voltages	**±0.1%** or **±50 mV** (the greater)
Phase-Ground, Phase-Phase, Ground and Synchronism	
Calculated voltages	
Phase-Phase (0 to 300V)	**±0.2%** or **±75 mV** (the greater)
VGround, V_1, V_2 and V_0	**±0.3%** or **±100 mV** (the greater)
Active and reactive powers (In = 5A and I_{phases}>1A)	
Angles 0º or ±90º or 180º	**±0.33% W/var**
Angles ±45º or ±135º	**±1.6% W/var**
Angles ±75º / ±115º	**±5% W** / **±0.65 % var**
Active energy	**Class 0.5** (*IEC 62053-22*)
Reactive energy	**Class 1** (*IEC 62053-24*)
Angles	**±0.5º**
Power factor	**±0.013**
Frequency	**±0.005 Hz**

Signal processing.

The setting of the analog input signal sampling function is achieved through frequency detection, calculated from the positive sequence voltage angle in DLX-B relays and the positive sequence current angle in DLX-A relays. The value of the calculated frequency is used to modify the sampling frequency used by the metering device attaining a constant sampling frequency of 32 samples per cycle. The frequency value is saved for later use in Protection and Control tasks.

The measurement of the frequency requires a minimum level of positive sequence voltage / current. In DLX-B relays, when the positive sequence voltage is below the "Inhibition Voltage" setting of the Frequency element, frequency measurement becomes impossible. The same happens for DLX-A when the positive sequence current is less than 100 mA. To the loss of the frequency calculation signal:

> *If the frequency measurement signal is below the minimum threshold for less than 2 s, the last calculated sampling rate is used. Once the 2 s have expired the sampling rate corresponding to the nominal frequency setting will be used.*

When Protection and Control tasks are readjusted in accordance with the sampling function, phasor real and imaginary components of analog signals are calculated by means of the Fourier transform. Fourier components are calculated by means of said Discrete Fourier Transform (DFT) using 32 sample/cycle. Using DFT this way the magnitude and phase angle of the fundamental component at power system frequency of every analog input signal is obtained. The rest of measurements and calculations of Protection functions is obtained based on the fundamental components calculated by the Fourier method. DFT gives a precise measurement of the fundamental frequency component and it is an efficient filter for harmonics and noise.

Harmonics are not completely damped for frequencies other than the nominal frequency. This is not a problem for small deviations of ±1Hz but, in order that a greater deviation from the working frequency can be allowed, the above-mentioned automatic adjustment of the sampling frequency is included. On lack of an adequate signal for sampling frequency adjustment, said frequency is adjusted to the corresponding nominal frequency (50/60Hz).

The angle reference for the measurements used by the differential function (local and remote measurements) will be the local current IA. For the rest of the measurements the reference will be the VA channel for DLX-B relays and the IA channel for DLX-A relays.

The sampling rate will be automatically set only if "PLL enable" has been set to YES, only editable through MMI.

2.1.7 Accuracy of the Pickup and Reset of the Differential Units

Differential Units	
Pickup and reset of Phases, Ground and Negative Sequence	**±3 %** or **±10mA** of the theoretical value (the greater) for **In** = **1A** and **5A**
Measuring Times	
Fixed Time	**±1 %** of the setting or **±25 ms** (the greater)
Inverse Time	**Class 2** (E = 2) or **±35 ms** (the greater) (UNE 21-136, IEC 255-4) (for measured currents of 100 mA or greater)

2.1.8 Accuracy of the Pickup and Reset of the Overcurrent Elements

Overcurrent Elements	
Pickup and reset of Phases and Ground	**±3 %** or **±10mA** of the theoretical value (the greater) for **In** = **1A** and **5A**
Pickup and reset of Sensitive Ground	**±3 %** or **±1mA** of the theoretical value (the greater)
Measuring Times	
Fixed Time	**±1 %** of the setting or **±25 ms** (the greater)
Inverse Time	**Class 2** (E = 2) or **±35 ms** (the greater) (UNE 21-136, IEC 255-4) (for measured currents of 100 mA or greater)

2.1.9 Accuracy of the Pickup and Reset of the Voltage Elements

Overvoltage and Undervoltage Elements	
Pickup and reset	**±2 %** or **±250 mV** of the theoretical value (the greater)
Measuring Times	
Fixed Time	**±1 %** of the setting or **±25 ms** (the greater)

2.1.10 Accuracy of the Pickup and Reset of the Frequency Elements

Overfrequency Elements	
Pickup and reset	**±0.01 Hz** of the theoretical value
Underfrequency Elements	
Pickup and reset	**±0.01 Hz** of the theoretical value
Measuring Times	
Fixed Time	**±1%** of the setting or **±25 ms** (the greater)

2.1.11 Repeatability

Operating Time	**2 %** or **25 ms** (the greater)

2.1.12 Transient Overreach

Expressed as: $ST = \frac{I_A - I_T}{I_A} x100$

<5%

I_A = Pick up value for a current with no dc component
I_T = Pick up value for a current with maximum dc offset

2.1.13 Digital Inputs

Configurable inputs with polarity (all the digital inputs are DC)

Nominal Voltage	Maximum Voltage	Burden	V on	V off
48 Vdc	90 Vdc	500 mW	30 Vdc	25 Vdc
125 Vdc	300 Vdc	800 mW	70 Vdc	65 Vdc
250 Vdc	500 Vdc	1 W	130 Vdc	96 Vdc

Undertaking coil circuit supervision limits the number of digital inputs available for other applications. Use of digital inputs is as follows:

Trip Coil Circuit Supervision	Used Inputs: **DI1**, **DI2** and **DI3**
Coil Circuit 2 Supervision	Used Inputs: **DI9**, **DI10** and **DI11**
Coil Circuit 3 Supervision	Used Inputs: **DI9**, **DI12** and **DI13**

2.1.14 Breaker Trip and Close Outputs and Auxiliary Outputs

It has **2** contacts that are normally open for operations (**TRIP** and **CLOSE**), the first of which can be configured to close internally, and **3** or **8** (according to model) auxiliary contacts that are normally open, including EQUIP. ALARM. The characteristics of all of them, apart from the **OUT7** contact, are as follows:

I DC maximum limit (with resistive load)	**60 A** (1 s)
I DC continuous service (with resistive load)	**16 A**
Close	**5000 W**
Breaking capability (with resistive load)	**240 W** - max. 5 A - (48 Vdc)
	110 W (80 Vdc - 250 Vdc)
	2500 VA
Break (L/R = 0.04 s)	**120 W** at 125 Vdc
Switching voltage	**250 Vdc**
Momentary close time trip contacts remain closed	**100 ms**
Break delay	
	<150 ms

OUT7 output has the following characteristics:

I DC maximum limit (with resistive load)	**30 A** (1 s)
I DC continuous service (with resistive load)	**8 A**
Close	**2500 W**
Breaking capability (with resistive load)	**150 W** - (48 Vdc)
	55 W (110 Vdc)
	1250 VA
Break (L/R = 0.04 s)	**60 W** at 125 Vdc
Switching voltage	**250 Vdc**

2.1.15 Input Transducers

0-5mA and ±2.5mA input transducers

Input impedance	**511 Ω**
Measurement accuracy	**±0.2 %** or **±3 µA** (the greater)

Voltage transducers (power supply monitoring for 125Vdc and 250 Vdc)

Measurement accuracy (between **70Vdc** and **350Vdc**)	**±0.2 %** or **±0.5 V** (the greater)

Voltage transducers (power supply monitoring for 24Vdc and 48 Vdc)

Measurement accuracy (between **10Vdc** and **70Vdc**)	**±0.2 %** or **±0.2 V** (the greater)

2.1.16 Communications Link for Differential Function dedicated Ports

Glass Fiber Optics	
Type	**Single Mode**
Wavelength	**1310 nm**
Connector	**ST**
Transmitter Minimum Power	**-3 dBm**
Receiver Sensitivity	**- 23 dBm**

2.1.17 Communications Link

Local Communications Port (RS232C)
Remote Communications Ports (GFO, PFO, RS232C, RS485)

Glass Fiber Optics (Remote Ports)	
Type	**Multimode**
Wavelength	**820 nm**
Connector	**ST**
Transmitter Minimum Power	
50/125 Fiber	**- 20 dBm**
62.5/125 Fiber	**- 17 dBm**
100/140 Fiber	**- 7 dBm**
Receiver Sensitivity	**- 25.4 dBm**

Plastic Fiber Optics (1 mm)	
Wavelength	**660 nm**
Transmitter Minimum Power	**- 16 dBm**
Receiver Sensitivity	**- 39 dBm**

RS232C Port Signals	
Terminal unit DB-9 (9-pin) connectors	**Pin 5 - GND**
	Pin 2 - RXD
	Pin 3 - TXD

RS485 Port Signals	
Used signals	**Pin 4 - (A) TX+ / RX+**
	Pin 6 - (B) TX- / RX-

IRIG-B 123 and 003	B: 100pps
1: Amplitude modulated wave	0: By pulse width
2: 1kHz/1ms	0: Without carrier
3: BCD, SBS	3: BCD, SBS

Type BNC connector

Input impedance	**211 Ω**
Maximum input voltage	**10 V**
Synchronization Accuracy	**± 1ms for Events labeling**
	± 25 us for Differential Unit synchronization

When the device is receiving a IRIG-B signal for synchronization both Date and Time settings will not be available through the HMI.

It is possible to configure one of the auxiliary outputs to check the IRIG-B signal status. This output will remain active as long as the IRIG-B signal reception is correct.

All the devices are also designed to give an indication for both the loss and recovery of such IRIG-B signal by generating the particular event.

2.2 Standards and Type Tests

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2.2.2 Electromagnetic Compatibility 2.2-2
2.2.3 Environmental Test 2.2-3
2.2.4 Power Supply 2.2-4
2.2.5 Mechanical Test 2.2-4

The equipment satisfies the standards indicated below. When not specified, the standard is IEC-60255.

2.2.1 Insulation

Insulation Test (Dielectric Strength)	*IEC-60255-5*
Between all circuit terminals and ground	**2 kV**, **50/60 Hz**, for 1 min; or **2.5 kV**, **50/60 Hz**, for 1s
Between all circuit terminals	**2 kV**, **50/60 Hz**, for 1min; or **2.5 kV**, **50/60 Hz**, for 1s
Measurement of Insulation Resistance	*IEC-60255-5*
Common mode	**R ≥ 100 MΩ** or **5μA**
Differential mode	**R ≥ 100 kΩ** or **5mA**
Voltage Impulse Test	*IEC-60255-5*
Common mode (analog inputs, DIs, AOs and PS)	**5 kV**; **1.2/50 μs**; **0.5 J**
Differential mode (AOs)	**1 kV**; **1.2/50 μs**
Differential mode (Power Supply)	**3 kV**; **1.2/50 μs**

2.2.2 Electromagnetic Compatibility

1 MHz Burst Test	*IEC-60255-22-1 Class III*
Common mode	**2.5kV**
Differential mode	**2.5kV**
Oscillatory Waves Immunity Test	*IEC-61000-4-12 100kHz and 1MHz Class III*
Common mode	**2.5kV**
Differential mode	**2.5kV**
Fast Transient Disturbance Test	*IEC-60255-22-4 Class IV* *(IEC 61000-4-4)* **4 kV ±10 %**
Radiated Electromagnetic Field Disturbance	*IEC 61000-4-3 Class III*
Amplitude modulated	**10 V/m**
Pulse modulated	**10 V/m**
Conducted Electromagnetic Field Disturbance	*IEC 61000-4-6 Class III*
Amplitude modulated	**10 V**
Electrostatic Discharge	*IEC 60255-22-2 Class IV* *(IEC 61000-4-2)*
On contacts	**±8 kV ±10 %**
In air	**±15 kV ±10 %**

Surge Immunity Test	*IEC-61000-4-5*
	(1.2/50µs - 8/20µs)
Between conductors	**4 kV**
Between conductors and ground	**4 kV**

Radiated Electromagnetic Field Disturbance at Industrial Frequency (50/60 Hz)	*IEC61000-4-8*

Radio Frequency Emissivity	*EN55022* (Radiated)
	EN55011 (Conducted)

2.2.3 Environmental Test

Temperature	*IEC 60068-2*
Cold work	*IEC 60068-2-1*
	-5º C, **2 hours**
Cold work limit conditions	*IEC 60068-2-1*
	-10º C, **2 hours**
Dry heat	*IEC 60068-2-2*
	+45º C, **2 hours**
Dry heat limit conditions	*IEC 60068-2-2*
	+55º C, **2 hours**
Humid heat	*IEC 60068-2-78*
	+40º C, **93%** relative humidity, **4 days**
Quick temperature changes	*IEC 60068-2-14 / IEC 61131-2*
	IED open,
	-25º C for **3h** and
	+70º C for **3h** (**5 cycles**)
Changes in humidity	*IEC 60068-2-30 / IEC 61131-2*
	+55º C for **12h** and
	+25º C for **12h** (**6 cycles**)
Endurance test	**+55º C** for **1000 hours**
Operating range	From **-40º C** to **+ 85º C**
Storage range	From **-40º C** to **+ 85º C**
Humidity	**95 %** (non-condensing)

Climate Test (55º, 99% humidity, 72 hours)

Time / Current Characteristic	*ANSI C37.60 Class II*

2.2.4 Power Supply

Power Supply Interference and Ripple	*IEC 60255-11* **< 20 %** and **100 ms**
Inverse Polarity of the Power Supply	*IEC 61131-2*
Resistance of Ground Connection	*IEC 61131-2* **< 0.1 Ω**
Gradual Stop / Start Test	*IEC 61131-2* (Test A)
Surge Capacity	*IEC 60044-1*

2.2.5 Mechanical Test

Vibration (sinusoidal) a) Answer: (equipment on). *Class II* b) Endurance: (equipment off). *Class I*	*IEC-60255-21-1*
Mechanical Shock and Bump Test	*IEC-60255-21-2 Class I*

The models comply with the EEC 89/336 standard of electromagnetic compatibility.

2.3 Physical Architecture

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2.3.1 General

The equipments are made up of the following modules:

- Processor module and HMI.
- Analog inputs module.
- Power Supply.
- Digital inputs, outputs and transducers inputs module.
- Communications module.

The modules are mounted vertically and can be extracted by removing the front panel. Do not require the dismantling of the front of the unit. External connection is carried out by means of plug-in terminal blocks (supported on the bearing strip located at the back of each module) for ring lug connectors for analogical inputs, and pointed hubs for digital inputs and outputs and for transducer inputs.

Depending on the terminal configuration, all the contact inputs / outputs may be used or some may remain as spare signals.

Next figures represent the external appearance of the **2DLX** models.

Mounted on the front are the alphanumeric keypad and display, the local communication ports (RS232C and USB), the local control buttons and the LED targets.

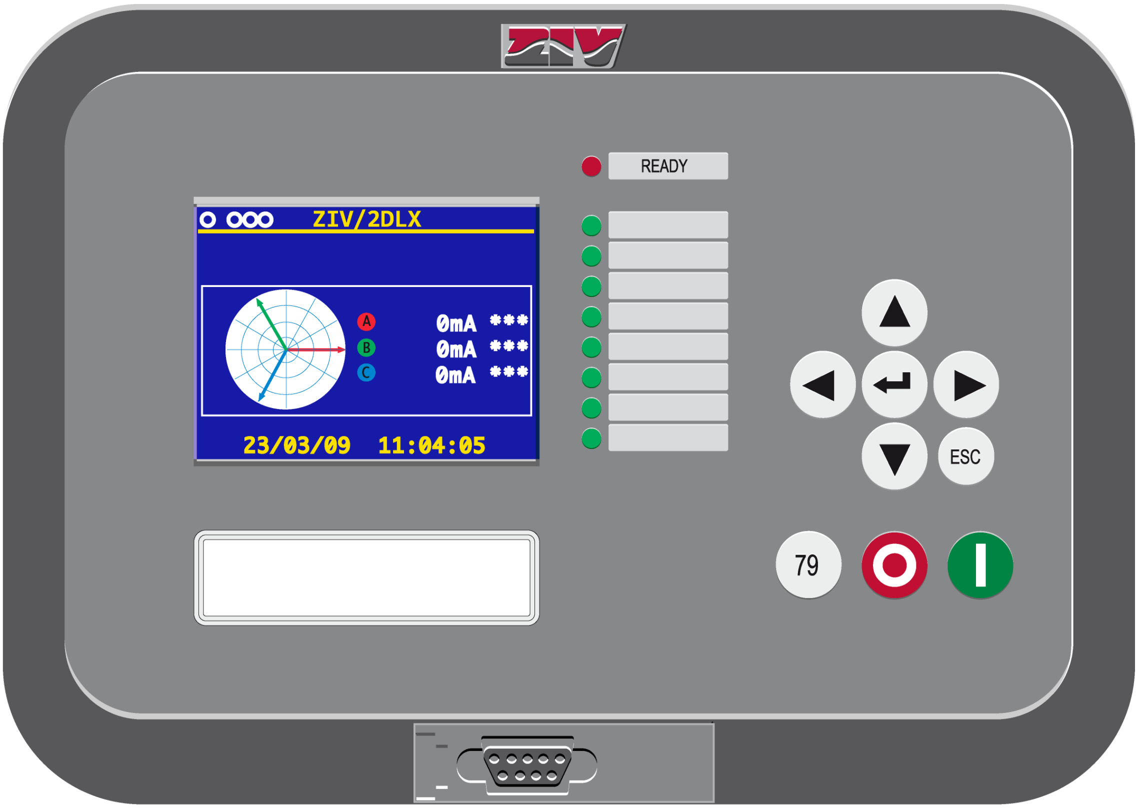


Figure 2.3.1 Front of a 2DLX.

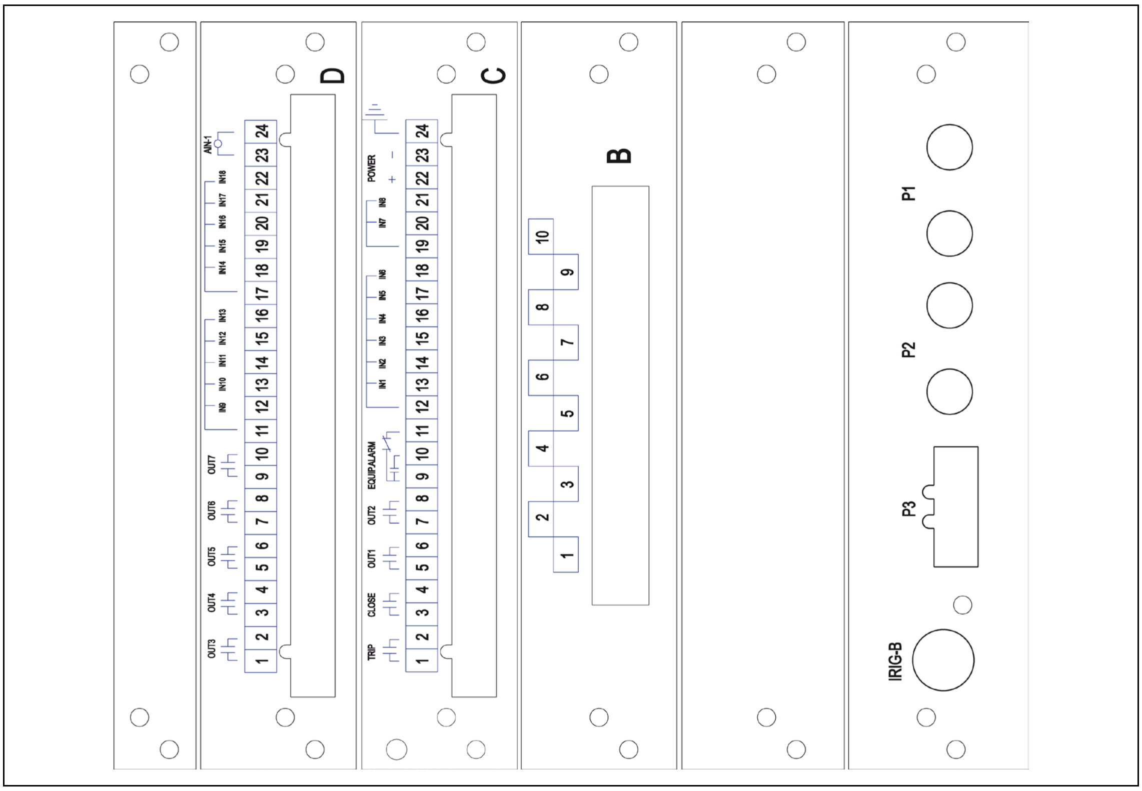


Figure 2.3.2 Rear of a 2DLX-A.

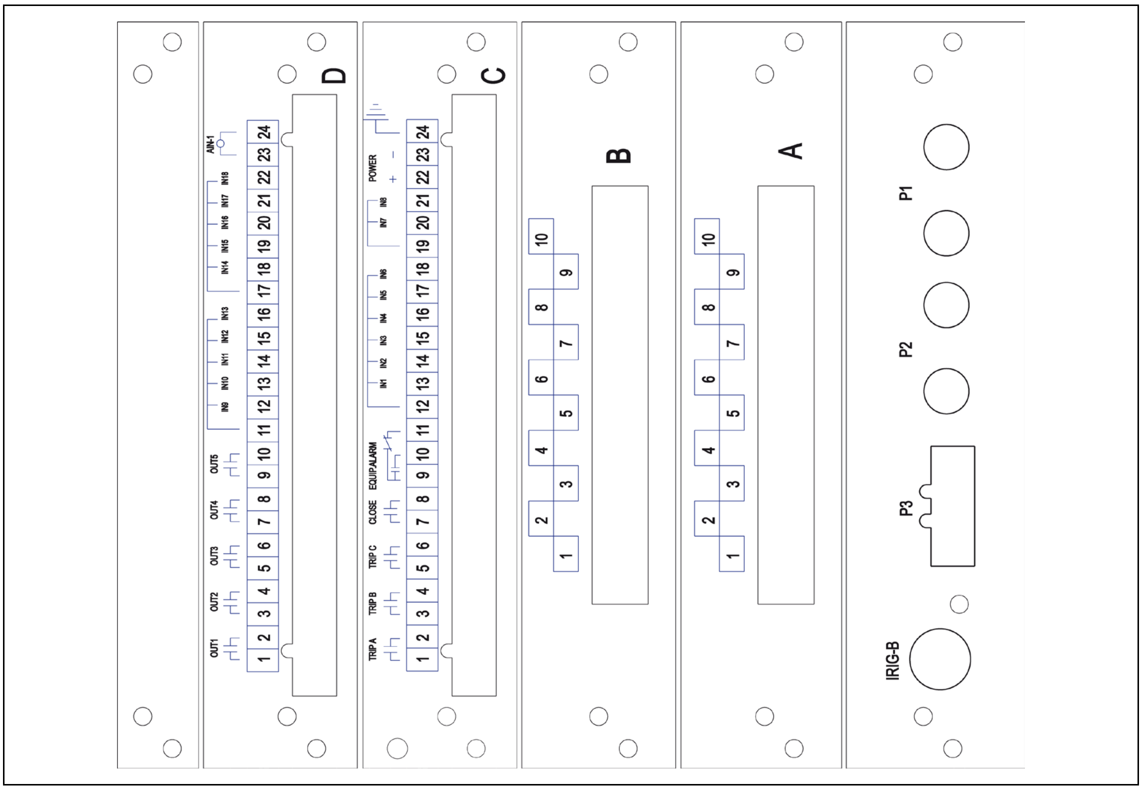


Figure 2.3.3 Rear of a 2DLX-B.

2.3.2 Dimensions

The equipment is intended to be installed either semi-flush mounted on panels or inside a 19” rack. The enclosure is graphite gray. The dimensions are 1/2 19" rack and 4 standard units high.

2.3.3 Connection Elements

2.3.3.a Terminal Blocks

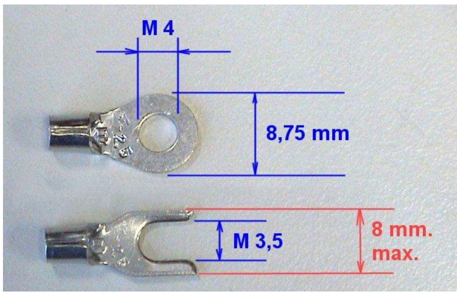
The number of connectors for the relays depends on the number of analogical inputs and the digital inputs / outputs of the specific model.

Terminal blocks are vertical as shown in the figure 2.3.2. The terminal arrangement for the **2DLX-A** model is as follows:

- 1 column for all the communication and synchronization connectors.
- 1 column with 1 terminal block of 10 terminals for analog currents plus all the remote communications and synchronization connectors.
- 1 column with 1 terminal block of 24 terminals for digital inputs, auxiliary outputs, trip and close contacts and power supply input.

As an option is possible to expand the number of digital inputs and outputs and one transducer input by adding one more column with 1 terminal block of 24 terminals.

The self-shorting ring lug terminals corresponding to the current analog inputs take wires up to #10 AWG (6 mm^2). We recommend ring lug terminals for these connections.



The connectors are plug-in and not self-shorting. They can be assigned to the current circuits supporting a current of 20 A continuously.

The terminals of the 24 terminals block admit a #13 AWG (2.5 mm^2) cable. Use of pointed hubs is recommended to connect to terminals.

2.3.3.b Removing Printed Circuit Boards (Non Self-shorting)

WARNING!

The IED's printed circuit board can be taken out. **WARNING: the current connector is non self-shorting. Consequently, the CT secondaries must be short-circuited externally before board removal.**

The printed circuit board is attached to the case with self-tapping screws. These screws must be removed before the board is withdrawn. This operation always requires the protection to be **not in service**.

2.3.3.c Internal Wiring

The equipment uses traditional printed circuit board connections and internal buses to minimize internal wiring.

Chapter 3.

Functions and Description of Operation

3.1 Differential Units

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3.1.1 Synchronization

DLX relays calculate phasors, at fundamental frequency, of phase currents IA, IB and IC and of positive sequence voltage, VSD (**DLX-B** models only), at instants separated 4 ms from each other. The meter for calculating instants goes from 0 to 24. The time between two consecutive Nº 0 instants is therefore 100 ms. Calculated phasors are sent to the remote end, with the number of the calculation time instant, via a 64 kbit/s channel. Remote currents received are compared with local currents corresponding to the same calculation time instant. In order for said comparison to be valid, clocks of both local and remote relays must be perfectly synchronized. Two ways of synchronization exist:

- Synchronization by communications.
- Synchronization by GPS.

3.1.1.a Synchronization by Communications

Relays operate according to a master - slave scheme. The relay designated as slave (**Master Relay** set to NO) is continually adapting its clock to the master relay clock. To this end, every 20 ms, at instants 0, 4, 9, 14 and 19, the slave relay sends a message to the master relay, which will respond with another message in which time data is included. The scheme, known as “ping-pong”, is shown in the figure.

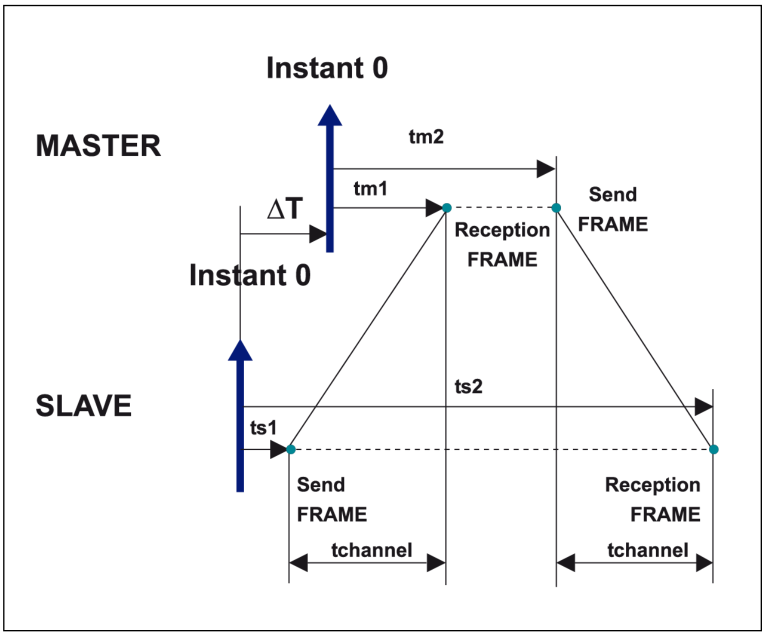

Figure 3.1.1 Synchronization by Communications Process.

The slave relay sends, at the instants mentioned above, a message to the other end, annotating the time lapse between calculation time instant nº 0 to the time when the frame is sent (time ts1). When the message is received by the master relay, this annotates the time lapse between time instant Nº 0 and when said message is received (time tm1). The next message leaving the master relay will include time tm1 and the time lapse between time instant nº 0 and when said message is sent (time tm2). Finally, when the message sent by the master relay is received by the slave relay, this annotates the time lapse between time instant nº 0 and when the full frame is received (time ts2).

The relationship between the time values shown in figure, assuming channel delay time is the same both ways, is as follows:

$$ts1 + t_{channel} = \Delta T + tm1$$
$$ts2 = \Delta T + tm2 + t_{channel}$$

From these two equations it follows:

$$t_{channel} = \frac{(ts2 - ts1) - (tm2 - tm1)}{2}$$
$$\Delta T = \frac{ts1 + ts2}{2} - \frac{(tm1 + tm2)}{2}$$

Every 10 measurements of ΔT a mean value (ΔT_{mean}) is obtained, so as to reduce possible channel "jitter". The position of time instant nº 0 will be corrected with the calculated ΔT_{mean} provided:

- Signal **Excessive Differential Channel Time** not active. For this to occur, channel time must be less than **Maximum Channel Time** setting.
- **Constant Differential Channel Time** signal active. For this to occur, channel time variation must be less than **Maximum Channel Time Variation** setting during **Maximum Channel Switching Time** setting.
- Calculated ΔT_{mean} is below a threshold.

In SDH networks, there are reset architectures that switch channels upon failure of any of the channels linking both relays. These can be bidirectional (both forward and reverse channels are modified,) or unidirectional (only the failed channel is modified). In both cases a variation in channel time is produced. When signal **Constant Channel Time** deactivates a ΔT_{mean} ($\Delta T_{frozen\ mean}$) historical file stored during the last seconds will be applied. Said file will only be available when channel time has remained constant for more than 10 seconds. On the other hand, it may only be used for one minute. When value $\Delta T_{frozen\ mean}$ is not available, signal constant channel time being deactivated, the differential element will cease to be available, and signal **Differential Unit Ready** will deactivate. If channel time becomes constant before one minute, the calculated ΔT_{mean} will be used again, provided it is below a threshold; otherwise the differential element will be disabled (deactivation of signal **Differential Unit Ready**). If a bidirectional switching has occurred, once channel time becomes constant, the calculated ΔT_{mean} will be very small, taking into account that the use of $\Delta T_{frozen\ mean}$ has kept a good synchronization between clocks. However, if a unidirectional switching has occurred, an asymmetry will be generated in the communications channel, with different forward and reverse times. In this case, the value of ΔT_{mean} will be equal to the difference between forward and reverse times divided by 2. As will be seen below, the directional comparison element (see section 3.4) allows communication channel asymmetries of up to 90º. That is why, when **Directional Comparison Blocking** setting is set to YES, values of ΔT_{mean} up to 85º may be applied (Tnom*85/360, where Tnom is the nominal period). If **Directional Comparison Blocking** setting is set to NO, the value of ΔT_{mean} to be applied will be less than **Maximum Channel Time Variation** setting.

Maximum Channel Time Variation setting shall be set bearing in mind the maximum allowable channel "jitter". **Maximum Channel Switching Time** setting must be set to the maximum time one of both communications channels may be switched, with an allowance of 200 ms, duration of the filter to obtain ΔT_{mean}.

DLX relays include two communications channels operating simultaneously. Only measurements from the channel with the best features are taken: faultless channel, with constant channel time, etc. Channels will only be switched upon worsening conditions of the channel in use, provided the parameters of the new channel are better than the switched channel.

DLX relays monitor both communications channels and activate signal **Differential Protection Channel n Communication Failure** (n=1, 2) when the following signals activate:

- **Open Differential Channel n**: indicates channel n (n=1, 2) opens.
- **Communications Failure at Port HDLC n** (n=1, 2): activates when no frame is received for 200 ms or erroneous frames are received.
- **Differential Channel n Not Available** (n=1, 2): it activates when severely erroneous frames are present for a time in seconds exceeding the **Severely Erroneous Seconds to Activate Channel Not Available** setting. Once it is activated, it deactivates when the time in consecutive seconds without erroneous frames exceeds the **Seconds without Error to Activate Channel Available** setting. The relay includes, for each channel, a meter to measure erroneous seconds (seconds with erroneous frames) and severely erroneous seconds (seconds with a number of erroneous seconds exceeding the **Erroneous Frames to Detect severely Erroneous Seconds** setting). **Reset Command for Channel n Error Meter Differential Protection** (n=1, 2) signals reset the latter meters to zero.
- **Unmatched Local and Remote Relay Address**. Activates when the remote address setting does not match the address received.
- **Excessive Channel Time**: activates when calculated channel time exceeds the **Maximum Channel Time** setting.

The relay incorporates the $\mathbf{T_{go} - T_{return}}$ setting to compensate, in synchronization by communications, for the difference between channel forward and reverse times. Said time may be calculated through tests previous to relay commissioning. This setting will only be meaningful if it remains constant.

Note: in order for the differential element to operate, one relay must be designated as master and the other not.

3.1.1.b Synchronization by GPS

Communications channel asymmetry (different forward and reverse time) causes a ∆T calculation error equal to (T_{go} - T_{return})/2, as channel time is calculated as the sum of forward time and reverse time divided by 2. The ∆T error translates into an angular error, (T_{go} - T_{return})*180*fnom, which may cause an erroneous operation of the differential element. Using of a GPS signal enables a precise synchronization of both relay clocks no matter communications channel asymmetries. The IRIG-B input through the rear connector BNC is used for synchronization. A digital IRIG-B signal (pulse modulated) is recommended, instead of an analog signal (amplitude modulated), so as to obtain adequate accuracy. The PPS signal (pulses per second) obtained from the IRIG-B signal marks the beginning of nº 0 calculation instant in both relays.

During synchronization by GPS, the relay measures the ∆T error produced by possible channel asymmetry. When the IRIG-B signal is lost at any end, the last ∆T error is frozen and the relay carries out synchronization by communications. In said synchronization the measured ∆T is corrected with the saved ∆T error, provided **Constant Differential Channel Time** signal is active. When channel time ceases to be constant as a consequence of channel switching, the saved ∆T error ceases to be applied.

It must be highlighted that if the IRIG-B signal is lost at any relay for long, the recovery of the same will result in significant change in clock phase, which will disable the Differential Element for 1 second.

Synchronization by GPS is enabled with **Synchronization by GPS** setting set to YES.

3.1.2 Communication between Relays and Differential Measurement

DLX relays incorporate two ports for the communications required by the Differential Element, with monomode fiber optic interface and ST connector. The optical gain of ports is 20dB. The distance reached without repeaters is about 24 km with 9/125um fiber optic and 1310nm wave length. This calculation has been done taking into account 4 connectors (ST type) between two relays (2dB attenuation per connector), 3 fiber optic couplings (0.2 dB attenuation per coupling), 0.35 dB/km fiber optic attenuation and 3dB loss due to system aging.

Communications baud rate between relays is 64 kbit/s and the frame includes the following data:

- 16 bit address and CRC.
- Phase current measurements IA, IB and IC.
- Positive sequence voltage measurement VSD (models **DLX-B**).
- Configurable digital signals: there are 14 digital signals that can be interchanged between both relays. They are known as virtual Inputs / Outputs and are configured the same as the physical relay inputs and outputs.
- Signals used for synchronization (constant channel time or excessive channel time signals, ΔT below threshold, active IRIG-B signal, etc).
- Signals on exceeding the minimum threshold setting of the phase directional comparison element (see section 3.4.2).
- Saturation detector activation signals (see section 3.4.3).

Currents IA, IB and IC received from the remote end are compared with local currents IA, IB and IC with the same time tags (same calculation instant). As CTs at both ends may have different transformation ratios (based on **Phase CT Ratio** and **Remote Phase CT Ratio** settings), the currents at both ends must be scaled before the comparison. For this the current with the minimum transformation ratio shall be selected (local or remote) and it shall be multiplied by the factor:

$$k_{curr} = \frac{Phase_{CT\_MIN}}{Phase_{CT\_MAX}}$$

The differential current will in this way be referred to the maximum transformation ratio.

Local and remote ground, negative sequence and positive sequence currents used by differential or directional comparison elements will be obtained from the corresponding phase currents.

3.1.3 Test Mode

When test mode is activated (**Test Mode** setting set to YES) the relay is prepared to receive messages from itself, making local and remote addresses equal, even though the corresponding settings are not equal. The two ports must be connected to each other by means of a monomode optical fiber pigtail (TX to RX and RX to TX). In this case the differential current will be 2 times the measured current.

3.1.4 Phase Differential Unit

Phase differential elements incorporate a dual slope percentage restraint characteristic as shown in figure 3.1.2.

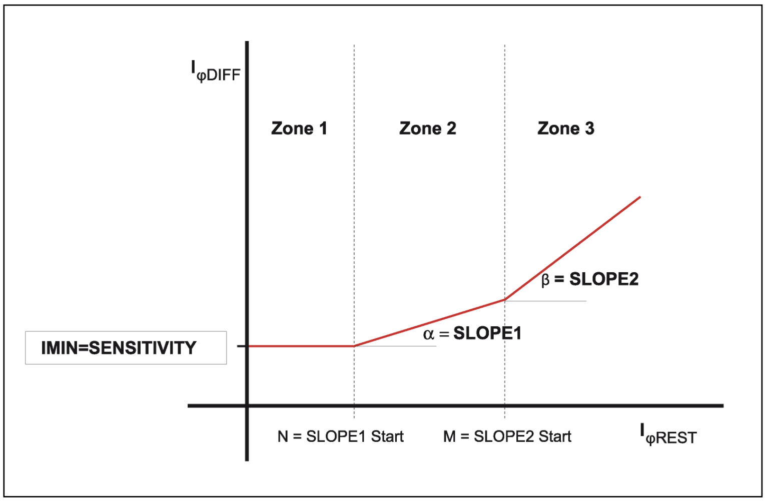

Figure 3.1.2 Percentage Characteristic of the Phase Differential Element.

Operating conditions are given by the following equations:

ZONE1: $$\left|I_{\phi DIEF}\right| > IMIN$$

ZONE 2: $$\left|I_{\phi DIFF}\right| > IMIN + \alpha \cdot \left(I_{\phi REST} - N\right)$$

ZONE 3: $$\left|I_{\phi DIFF}\right| > IMIN + \alpha \cdot (M - N) + \beta \cdot \left(I_{\phi REST} - M\right)$$

$$I_{\phi DIFF} = \left|I_{\phi L} + I_{\phi R}\right|$$

where

$I_{\phi DIFF}$	is the differential current of phase Φ (Φ=A, B, C).
$I_{\phi L}$	is the local current of phase Φ (Φ=A, B, C).
$I_{\phi R}$	is the remote current of phase Φ (Φ=A, B, C).

Two types of restraint exist, selected by a setting:

$$I_{\phi REST1} = \frac{\left|I_{\phi L}\right| + \left|I_{\phi R}\right| - \left|I_{\phi DIFF}\right|}{2} \qquad I_{\phi REST2} = \frac{\left|I_{\phi L}\right| + \left|I_{\phi R}\right|}{2}$$

Note: local and remote currents included in formulas shall be already scaled with the Kcurr factor in accordance with the criterion mentioned in section 3.1.2.

After tripping, the element will not be reset until the differential current drops below 0.8*IMIN.

3.1.5 Ground Differential Unit

The load flux increases the restraint current without changing the differential current (the differential current under load conditions is practically zero), moving point (I_{DIFF}, I_{REST}) to the right, as shown in figure 3.1.3. This effect may cause a lack of response of the phase differential element on weak feed defects (very resistive faults, very weak source faults, etc) and high load flux.

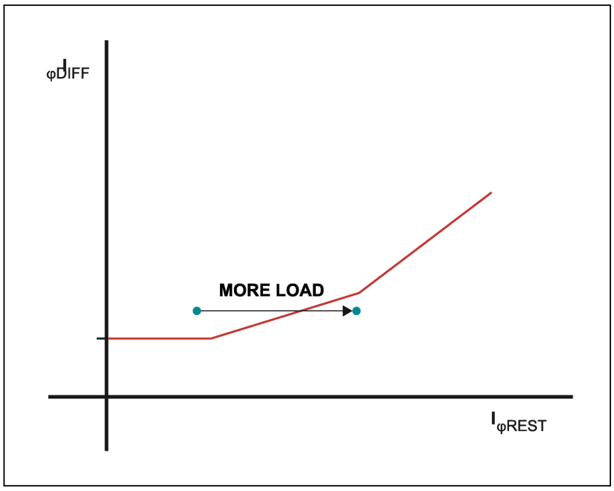

Figure 3.1.3 Effect of the Load on Phase Differential Element.

The Ground Differential element is not affected by the load, as the ground current is practically zero under load conditions. As the restraint current is based on ground current, the load flux does not increase. This allows increasing the sensitivity in the presence of the above mentioned faults.

In open pole conditions (single phase reclose cycle) **DLX-B** relays remove the prefault ground current so as to keep cancelling the effect of the load.

The ground differential element incorporates a dual slope percentage restraint characteristic as shown in figure 3.1.4.

$$|I_{DIFFG}| = |I_{LG} + I_{RG}|$$

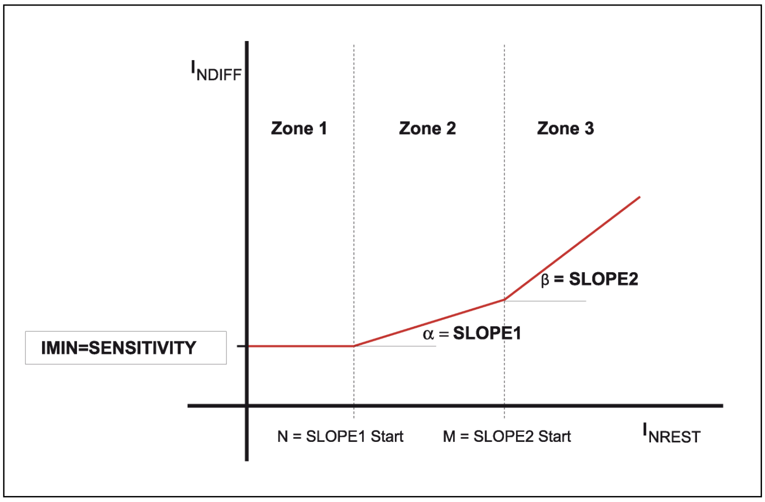

Figure 3.1.4 Percentage Characteristic of the Ground Differential Element.

Where:

I_{DIFFG}	is the ground differential current
I_{LG}	is the local ground current
I_{RG}	is the remote ground current

Two types of restraint exist, selected by setting:

$$I_{RESTG1} = \frac{|I_{LG}| + |I_{RG}| - |I_{DIFFG}|}{2} \qquad I_{RESTG2} = \frac{|I_{LG}| + |I_{RG}|}{2}$$

Note: local and remote currents included in formulas shall be already scaled with the Kcurr factor in accordance with the criterion mentioned in section 3.1.2.

Operating conditions are given by the following equations:

ZONE1: $|I_{DIFFG}| > IMIN$

ZONE 2: $|I_{DIFFG}| > IMIN + \alpha \cdot (I_{RESTG} - N)$

ZONE 3: $|I_{DIFFG}| > IMIN + \alpha \cdot (M - N) + \beta \cdot (I_{RESTG} - M)$

The Ground Differential Element will only operate when the phase selector (see section 3.2) indicates ground fault without two or more currents greater than 2*Inom provided that, in this latter case, I0/I1<1.25 **(I0 is the zero sequence current and I1 is the positive sequence current)**.

After tripping, the element will not be reset until the differential current drops below 0.8*IMIN.

3.1.6 Negative Sequence Differential Unit

The Negative Sequence Differential Element has the same sensitivity as the Ground Differential Element on faults with weak feed and high load flux, with the advantage that it can also operate on pure two phase faults, without ground connection.

In open pole conditions (single phase reclose cycle) **DLX-B** relays remove the prefault negative sequence current so as to keep cancelling the effect of the load.

The negative sequence differential element features a dual slope percentage restraint characteristic as shown in figure 3.1.5.

$$|I_{2DIFF}| = |I_{2L} + I_{2R}|$$

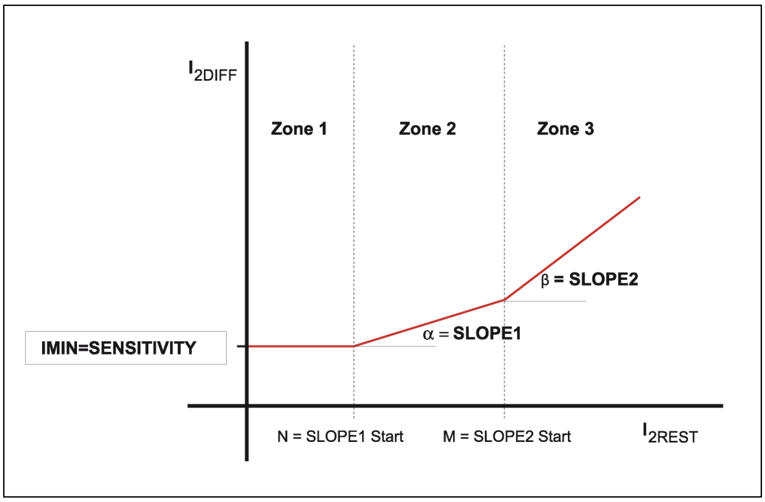

Figure 3.1.5 Percentage Characteristic of the Negative Sequence Differential Element.

Where:

I_{2DIFF}	is negative sequence differential current
I_{2L}	is negative sequence local current
I_{2R}	is negative sequence remote current

Two types of restraint exist, selected by setting:

$$I_{2REST1} = \frac{|I_{2L}| + |I_{2R}| - |I_{2DIFF}|}{2} \qquad I_{2REST2} = \frac{|I_{2L}| + |I_{2R}|}{2}$$

Note: local and remote currents included in formulas shall be already scaled with the Kcurr factor in accordance with the criterion mentioned in section 3.1.2.

Operating conditions are given by the following equations:

ZONE1: $|I_{2DIFF}| > IMIN$

ZONE 2: $|I_{2DIFF}| > IMIN + \alpha \cdot (I_{2REST} - N)$

ZONE 3: $|I_{2DIFF}| > IMIN + \alpha \cdot (M - N) + \beta \cdot (I_{2REST} - M)$

After tripping, the element will not be reset until the differential current drops below 0.8*IMIN.

The Negative Sequence Differential Element will only operate when the Phase Selector (see section 3.2) does not indicate three phase fault and there are not three currents greater than 2*Inom.

It is possible that both differential elements, ground and negative phase, are single phase (see section 3.19, trip logic). To that effect **Single Phase Trip 87G** must be set to **YES**.

3.1.7 Capacitive Current Compensation (DLX-B Models)

In long lines or cables the current bypassed through the capacitance (ground or between phases) may cause a significant differential current under load conditions. In order to prevent tripping under this condition the sensitivity level must be increased, which, obviously, limits relay response. In order to be able to reduce the sensitivity setting, the current bypassed through the capacitance can be removed from the total differential current. To this effect phase voltages must be measured and positive sequence and zero sequence line capacities must be known.

Considering a PI circuit equivalent to the line, with admittance Y/2 concentrated at each end of the line, the capacitive current at each end will be:

$$\left[(V_{1\phi} - V_0)\cdot\frac{Y_1}{2}\right] - (V_0\cdot\frac{Y_0}{2})$$

Where:

$V_{1\phi}$	is the positive sequence voltage of phase Φ (Φ=A, B, C).
V_0	is the zero sequence voltage
Y_1	is the total positive sequence admittance of the line, calculated from y1 (positive sequence admittance of the line per unit length), z1 (positive sequence impedance of the line per unit length and L (length of the line)
Y_0	is the total zero sequence admittance of the line, calculated from y0 (zero sequence admittance of the line per unit length), z0 (zero sequence impedance of the line per unit length and L (length of the line)

$$\frac{Y_1}{2} = \frac{y_1\cdot L}{2}\cdot\frac{th\left(\frac{\gamma_1\cdot L}{2}\right)}{\frac{\gamma_1\cdot L}{2}}$$, where $\gamma_1 = \sqrt{(R1 + jwL1)\cdot(G1 + jwC1)} = \sqrt{z1\cdot y1}$

is the positive sequence propagation constant of the line and L the length of the line.

$$\frac{Y_0}{2} = \frac{y_0\cdot L}{2}\cdot\frac{th\left(\frac{\gamma_0\cdot L}{2}\right)}{\frac{\gamma_0\cdot L}{2}}$$, where $\gamma_0 = \sqrt{(R0 + jwL0)\cdot(G0 + jwC0)} = \sqrt{z0\cdot y0}$

is the zero sequence propagation constant of the line and L the length of the line.

To remove the capacitive current, the local phase current obtained for each end, $I_{\phi L}$, will be replaced by:

$$I_{\phi L} - \left[\left(V_{1\phi L} - V_{0L} \right) \cdot \frac{Y_1}{2} \right] - (V_{0L} \cdot \frac{Y_0}{2})$$

Capacitive current compensation will be applied when **Capacitive Current Compensation** setting is set to **YES**, **Capacitive Current Compensation Enable** input is active provided **Fuse Failure Blocking** and **Open Pole** signals are not activated.

3.1.8 Close-onto-Fault Sensitivity

Line energization produces a high frequency transient capacitive current that is superimposed to the steady state current. Although the relay filter greatly reduces high frequency signals, the differential current calculated during energizing may be slightly greater than the current obtained once steady state has been reached. In order to prevent erroneous relay operation, the sensitivity setting of the Differential Element must be increased for a little time. The new sensitivity will be defined by **CSF Sensitivity** setting and will be applied during a time pulse equal to **Close-onto-Fault** setting. The beginning of said pulse will be given by the activation of: **Close Command**, **Reclose Command**, **External Manual Close Input** or **External Reclose Input**.

3.1.9 Recommended Settings

3.1.9.a Type of Restraint Current

While the differential current in a fault external to the protected line is small, the first restraint current, **(I1+I2-Id)/2**, will be similar to the second restraint current, **(I1+I2)/2**. However, in a fault internal to the line, the first restraint magnitude will be rather smaller than the second (if the influence of the load is negligible, as the local and remote currents are in phase, the first restraint current will be zero). In this way, the compromise between safety and response of the first restraint formula is better than the second formula. However, it must be taken into account that, when significant differential currents are generated in external faults as a consequence, for instance, of the saturation of a CT, the first restraint current will be less than the second, which implies a reduction in safety. In any case, if **Directional Comparison Blocking** is enabled (see section 3.4), which gives a great differential element stability on external faults with saturation of a CT, the use of the first restraint current formula is recommended, as this increases the response on faults external to the line.

3.1.9.b Phase Differential Unit

- **Sensitivity**

The **Sensitivity** setting defines the minimum differential current required by the Differential Element to operate. Its value depends on the capacitance current, or line to earth leakage current due to line capacitance. As mentioned in section 3.1.8, when the line is energized, a transient capacitive current higher than the steady state current is generated. The same happens when an external fault is cleared as a result of a voltage increase, although in this case the magnitude of the transient capacitive current will be much smaller than during line energization.

DLX relays include a **Close-onto-Fault Sensitivity** setting, as mentioned in section 3.1.8. Said sensitivity will be applied, for a period equal to **Close-onto-Fault Time** setting, from the moment the line is energized (breaker closing). This has been designed to prevent tripping under energizing transients. If capacitive current compensation is not enabled, a value 3 times the steady state capacitive current is sufficient. If the latter function is enabled, the close onto fault sensitivity may be reduced to 1.5 times the steady state capacitive current. **Close-onto-Fault Time** must be greater than the transients duration. A value of 300 ms is normally sufficient.

Below is described the calculation procedure for steady state capacitive current.

Normal **Sensitivity** must be set so as to prevent tripping under minimum load conditions (minimum restraint current and maximum capacitive current, as voltage equals nominal voltage). If capacitive current compensation is not enabled, a value of 2 times the steady state capacitive current is adequate to prevent incorrect operation on transients resulting from clearance of external faults. If the capacitive current compensation is enabled, the sensitivity may be set to the same value as the steady state capacitive current.

In any case, both sensitivities must always be greater than 15% the nominal current.

The steady state capacitive current is calculated as:

$$I_C(A) = \frac{V_{nom}(V)}{\sqrt{3}} \cdot y(S/km) \cdot L(km)$$

Where:

Ic is the capacitive current in amps
Vnom is the line nominal voltage in volts
y is the admittance in Siemens per unit length
L is the length of the line

Example: let us assume a 110 kV cable with admittance y=95 uS/Km and a length of 10 km. Capacitive current will be:

$$I_C(A) = \frac{110 \cdot 10^3 (V)}{\sqrt{3}} \cdot 95 \cdot 10^{-6} (S/km) \cdot 10(km) = 60.33\ A\ primary$$

- **First Restraint Slope**

The object of the **First Restraint Slope** is to compensate for percentage errors, as a function of the current flow. Said errors are generated by CTs (in the unsaturated condition), by communications channel asymmetry (unequal forward and reverse times) and by the relay itself. It is worth mentioning that capacitive current has already been taken into account when setting the sensitivity, for which the maximum steady state capacitive current is calculated. This will occur under minimum load conditions, with nominal voltage. On external faults, as the voltage drops, the capacitive current will be smaller.

The percentage error introduced by the asymmetry is calculated as follows:

The phase difference produced by said asymmetry, in degrees, will be:

$\varphi = (t_{forward} - t_{reverse}) \cdot 180 \cdot f_{nom}$, where

T_{go}* - *T_{return} is the difference between forward and reverse times in seconds
f_{nom} is the nominal frequency in Hertz

Said phase difference, φ, generates a differential current: $I_{diff} = 2 \cdot sen\left(\frac{\varphi}{2}\right) \cdot I$ where

I is the current flow at both ends of the line.

Example

Let us assume a communications system with a difference between forward and reverse times of 1 ms.

$$\varphi = 0.001 \cdot 180 \cdot 50 = 9^o$$

$$I_{diff} = 2 \cdot sen\left(\frac{9}{2}\right) \cdot I = 0.16 \cdot I$$

Assuming $I_{rest} = 1$

$$I_{diff} = 0,16 \cdot I_{rest}$$

The error caused by the asymmetry is therefore 16%.

The error introduced by **CTs** depends on their accuracy class. For a TI 5P a maximum error of 5% can be considered. Assuming the errors of the CTs at both ends of the line have opposite signs, a 10% total error will be considered.

The error introduced by the **relay** will be less than 5%.

Allowing a safety margin, in this example the first restraint slope may be set to 35%.

If the sensitivity has been set to compensate only for line capacitive current, the **First Slope Start** must be set to the minimum value: 0 A.

- **Second Restraint Slope**

The **Second Slope Start** must be calculated taking into account the minimum current, in external fault conditions, which may cause saturation of any of the CTs. The restraint slope will be set to compensate for the differential current generated in this condition. A value of 80% is usually adequate, taking into account that directional comparison elements (see section 3.4) provide great security on external faults with saturation of some CTs.

3.1.9.c Ground Differential Element

- **Sensitivity**

It is calculated based on ground capacitive current under minimum load conditions. In this situation a small ground voltage may be generated in untransposed lines. Said capacitive current will be calculated as: $IN_C(A) = 3 \cdot V0\,(V) \cdot y\,0\,(S/km) \cdot L(km)$, where:

INc	is the ground capacitive current in amp
V0	is the zero sequence voltage under minimum load conditions in volt
y0	is the zero sequence admittance in Siemens per unit length
L	is the length of the line

The ground capacitive current increases as the ground current increases, as the neutral to ground voltage is proportional to this current. As the error introduced by ground capacitance is proportional to the current flow this will be compensated by means of the first restraint slope (see next section).

During line energization a ground capacitive current will be produced greater than the steady state current. The **Close-onto-Fault Sensitivity** will be set to the same value as the close onto fault sensitivity of the phase differential element.

Normal **Sensitivity** will be set to 2 times the above calculated value or 15% of the nominal current.

- **First restraint slope**

The function of the **First Restraint Slope** is to compensate for percentage errors, as a function of the current flow. Said errors are generated by the capacitive current, by CTs (in the unsaturated condition), by communications channel asymmetry (unequal forward and reverse times) and by the relay itself.

The percentage error introduced by the **capacitive current** is calculated as follows: $IN_C(A) = 3 \cdot V0 \cdot y\,0 \cdot L$, taking into account that:

- For forward fault: $V0 = -\,I0 \cdot (Z0SL)$, where Z0SL is the zero sequence impedance of the local source
- For reverse fault: $V0 = I0 \cdot (Z0SR + ZL0)$ where Z0SR is the zero sequence impedance of the remote source and ZL0 is the zero sequence impedance of the line

It can be considered that: $V0 = I0 \cdot K$ where $K = max\,(Z0SR + ZL0, ZS0)$.

If the following approximation is made:

$$IN_{diff} = 3 \cdot K \cdot y0 \cdot L \cdot I0$$

$$Irest = 3 \cdot I0$$

The percentage of error introduced by the capacitive current will be $K \cdot y0 \cdot L$

Example

Assuming a system with the following impedances:

Z0SL = 5 ohm
Z0SR = 8 ohm
Z0L = 12 ohm
y0 = 70 us/km
L = 10 km

K = 12 ohm

K*y0*L = 0.014

The percentage error introduced by the capacitive current will be 1.4%.

The calculation of the percentage error introduced by CTs, by communications channel asymmetry and by the relay will be the same as for the phase differential element. Said errors will be added to the error introduced by line capacitance.

The beginning of the first slope will be set to the minimum value (0 A).

- **Second Restraint Slope**

The **Second Slope Start** must be calculated taking into account the minimum ground current, in external fault conditions, which may cause saturation of any of the CTs. The restraint slope will be set to compensate for the differential current generated in this condition. A value of 80% is usually adequate, taking into account that directional comparison elements (see section 3.4) provide great security on external faults with saturation of some CTs.

The ground differential element is designed to clear faults with weak feed, for which the sensitivity of the phase differential element is not sufficient. That is why its operation is not needed on faults with high current flow. The operation of the ground differential element may be blocked if the ground current exceeds a given threshold. For this, both element block and enable inputs may be used. Through the programmable logic a ground overcurrent element output may be “wired” to one of the two inputs. With this logic, the use of a second restraint slope steeper than the first slope is not required.

3.1.9.d Negative Sequence Differential Unit

The setting criteria of the negative sequence differential element will be the same as for the ground differential element simply by replacing the zero sequence network by the negative sequence network. The factor 3 to convert zero sequence current into ground current will not be used.

3.1.10 Differential Unit Settings

Line Impedance (DLX-B Model)			
Setting	**Range**	**Step**	**By Default**
Positive Sequence Impedance Magnitude	0.001 - 10 ohm/L	0.001 ohm/L	0.5 ohm/L
Positive Sequence Impedance Angle	0 - 90º	0.1º	75º
Zero Sequence Impedance Magnitude	0.001 - 10 ohm/L	0.001 ohm/L	0.5 ohm/L
Zero Sequence Impedance Angle	0 - 90º	0.1º	75º
Positive Sequence Admittance Magnitude	0.1 - 1000 uS/L	0.001 uS/L	5 uS/L
Positive Sequence Admittance Angle	0 - 90º	0.1º	90º
Zero Sequence Admittance Magnitude	0.1 - 1000 uS/L	0.001 uS/L	5 uS/L
Zero Sequence Admittance Angle	0 - 90º	0.1º	90º
Line Length	0.01 - 1000 length units	0.01	50

General Settings			
Setting	**Range**	**Step**	**By Default**
Restraint Current Type	(I1+I2-Id)/2 (I1+I2)/2		(I1+I2-Id)/2
Close onto Fault Time	2 - 2000 ms	2 ms	300 ms
Test Mode	YES / NO		NO
Directional Comparison Blocking	YES / NO		YES
Capacitive Current Compensation (DLX-B)	YES / NO		NO

Communications Settings			
Setting	**Range**	**Step**	**By Default**
Master Device	YES / NO		NO
Local Address	0 - 4095	1	0
Remote Address	0 - 4095	1	0
GPS Synchronization	YES / NO		NO
Tgo - Treturn	-10 to 10 ms	0.1 ms	0
Maximum Channel Time	0 - 80 ms	0.1 ms	10 ms
Maximum Channel Switching Time	0.02 - 2 s	0.02 s	0.5 s
Maximum Jitter in the Channel	0.1 - 4 ms	0.05 ms	0.5 ms

Phase Differential Unit			
Setting	**Range**	**Step**	**By Default**
Enable	YES / NO		YES
Sensitivity	0.1*In - 2*In	0.01 A	0.3*In
Sensitivity for Close onto Fault	0.1*In - 2*In	0.01 A	0.5*In
Slope 1 Start	0 - 5*In	0.01 A	1*In
Slope 2 Start	0.5*In - 30*In	0.01 A	5*In
Slope 1	5 - 100%	0.01%	25%
Slope 2	10 - 200%	0.01%	100%
Time Delay	0 - 300 sec.	0.01 sec.	0 sec.

Ground Differential Unit			
Setting	**Range**	**Step**	**By Default**
Enable	YES / NO		YES
Sensitivity	0.1*In - 2*In	0.01 A	0,3*In
Sensitivity for Close onto Fault	0.1*In - 2*In	0.01 A	0,5*In
Slope 1 Start	0 - 5*In	0.01 A	1*In
Slope 2 Start	0.5*In - 30*In	0.01 A	5*In
Slope 1	5 - 100%	0.01%	25%
Slope 2	10 - 200%	0.01%	100%
Time Delay	0 - 300 sec.	0.01 sec.	0 sec.

Negative Sequence Differential Unit			
Setting	**Range**	**Step**	**By Default**
Enable	YES / NO		YES
Sensitivity	0.1*In - 2*In	0.01 A	0.3*In
Sensitivity for Close onto Fault	0.1*In - 2*In	0.01 A	0.5*In
Slope 1 Start	0 - 5*In	0.01 A	1*In
Slope 2 Start	0.5*In - 30*In	0.01 A	5*In
Slope 1	5 - 100%	0.01%	25%
Slope 2	10 - 200%	0.01%	100%
Time Delay	0 - 300 sec.	0.01 sec.	0 sec.

- **Differential Units: HMI Access (DLX-A Model)**

0 - CONFIGURATION	0 - GENERAL	**0 - LINE DIFFERENTIAL**
1 - OPERATIONS	**1 - PROTECTION**	1 - OPEN POLE LOGIC
2 - ACTIVATE GROUP	2 - RECLOSER	2 - OVERCURRENT
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN PHASE DETECTOR
4 - INFORMATION	...	4 - CT SUPERVISION
		5 - THERMAL IMAGE
		6 - COLD LOAD
		7 - BREAKER FAILURE
		8 - POLE DISCREPANCY
		9 - PHASE SELECTOR
		10 - PROTECTION LOGIC

0 - LINE DIFFERENTIAL	**0 - GENERAL**	**0 - RESTRAINT TYPE**
1 - OPEN POLE LOGIC	1 - COMMUNICATIONS	**1 - COF TIME**
2 - OVERCURRENT	2 - PHASE DIFFERENTIAL	**2 - TEST MODE**
3 - OPEN PHASE DETECTOR	3 - GROUND DIFFERENTIAL	**3 - DIR. COMP. BLOCK**
4 - CT SUPERVISION	4 - NEG. SEQ. DIFFERENTIAL	
...	5 - PHASE DIR. COMP.	
	6 - GROUND DIR. COMP.	
	7 - POS. SEQ. DIR. COMP.	
	8 - NEG. SEQ. DIR. COMP.	

0 - LINE DIFFERENTIAL	0 - GENERAL	**0 - MASTER DEVICE**
1 - OPEN POLE LOGIC	**1 - COMMUNICATIONS**	**1 - LOCAL ADDRESS**
2 - OVERCURRENT	2 - PHASE DIFFERENTIAL	**2 - REMOTE ADDRESS**
3 - OPEN PHASE DETECTOR	3 - GROUND DIFFERENTIAL	**3 - GPS SYNCHRONIZATION**
4 - CT SUPERVISION	4 - NEG. SEQ. DIFFERENTIAL	**4 - TGO - TRETURN**
...	5 - PHASE DIR. COMP.	**5 - MAX. CHANNEL TIME**
	6 - GROUND DIR. COMP.	**6 - MAX. SWITCH TIME**
	7 - POS. SEQ. DIR. COMP.	**7 - MAX. JITTER**
	8 - NEG. SEQ. DIR. COMP.	**8 - ER. FR SEV. ER SEC**
		9 - SEV. ER. SEC. UNAV
		10 - NON-ER. SEC. AVAIL

0 - LINE DIFFERENTIAL	0 - GENERAL	**0 - ENABLE**
1 - OPEN POLE LOGIC	1 - COMMUNICATIONS	**1 - SENSITIVITY**
2 - OVERCURRENT	**2 - PHASE DIFFERENTIAL**	**2 - SENSITIVITY COF**
3 - OPEN PHASE DETECTOR	3 - GROUND DIFFERENTIAL	**3 - SLOPE 1**
4 - CT SUPERVISION	4 - NEG. SEQ. DIFFERENTIAL	**4 - SLOPE 1 START**
...	5 - PHASE DIR. COMP.	**5 - SLOPE 2**
	6 - GROUND DIR. COMP.	**6 - SLOPE 2 START**
	7 - POS. SEQ. DIR. COMP.	**7 - TIME DELAY**
	8 - NEG. SEQ. DIR. COMP.	

0 - LINE DIFFERENTIAL	0 - GENERAL	**0 - ENABLE**
1 - OPEN POLE LOGIC	1 - COMMUNICATIONS	**1 - SENSITIVITY**
2 - OVERCURRENT	2 - PHASE DIFFERENTIAL	**2 - SENSITIVITY COF**
3 - OPEN PHASE DETECTOR	**3 - GROUND DIFFERENTIAL**	**3 - SLOPE 1**
4 - CT SUPERVISION	4 - NEG. SEQ. DIFFERENTIAL	**4 - SLOPE 1 START**
...	5 - PHASE DIR. COMP.	**5 - SLOPE 2**
	6 - GROUND DIR. COMP.	**6 - SLOPE 2 START**
	7 - POS. SEQ. DIR. COMP.	**7 - TIME DELAY**
	8 - NEG. SEQ. DIR. COMP.	

0 - LINE DIFFERENTIAL	0 - GENERAL	**0 - ENABLE**
1 - OPEN POLE LOGIC	1 - COMMUNICATIONS	**1 - SENSITIVITY**
2 - OVERCURRENT	2 - PHASE DIFFERENTIAL	**2 - SENSITIVITY COF**
3 - OPEN PHASE DETECTOR	3 - GROUND DIFFERENTIAL	**3 - SLOPE 1**
4 - CT SUPERVISION	**4 - NEG. SEQ. DIFFERENTIAL**	**4 - SLOPE 1 START**
...	5 - PHASE DIR. COMP.	**5 - SLOPE 2**
	6 - GROUND DIR. COMP.	**6 - SLOPE 2 START**
	7 - POS. SEQ. DIR. COMP.	**7 - TIME DELAY**
	8 - NEG. SEQ. DIR. COMP.	

- **Differential Units: HMI Access (DLX-B Model)**

0 - CONFIGURATION	0 - GENERAL	**0 - LINE DIFFERENTIAL**
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	4 - OVERCURRENT
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - LINE DIFFERENTIAL	**0 - GENERAL**	**0 - RESTRAINT TYPE**
1 - FUSE FAILURE	1 - LINE IMPEDANCE	**1 - COF TIME**
2 - DEAD LINE DETECTOR	2 - COMMUNICATIONS	**2 - TEST MODE**
3 - OPEN POLE LOGIC	3 - PHASE DIFFERENTIAL	**3 - DIR. COMP. BLOCK**
4 - OVERCURRENT	4 - GROUND DIFFERENTIAL	**4 - CAPAC. CURR. COMP.**
...	5 - NEG. SEQ. DIFFERENTIAL	
	6 - PHASE DIR. COMP.	
	7 - GROUND DIR. COMP.	
	8 - POS. SEQ. DIR. COMP.	
	9 - NEG. SEQ. DIR. COMP.	

0 - LINE DIFFERENTIAL	0 - GENERAL	**0 - POS. SEQ. MAGNITUDE**
1 - FUSE FAILURE	**1 - LINE IMPEDANCE**	**1 - POS. SEQ. ANGLE**
2 - DEAD LINE DETECTOR	2 - COMMUNICATIONS	**2 - ZERO SEQ. MAGNITUDE**
3 - OPEN POLE LOGIC	3 - PHASE DIFFERENTIAL	**3 - ZERO SEQ. ANGLE**
4 - OVERCURRENT	4 - GROUND DIFFERENTIAL	**4 - POS. SEQ. ADMIT.**
...	5 - NEG. SEQ. DIFFERENTIAL	**5 - POS. SEQ. ADMIT. ANG.**
	6 - PHASE DIR. COMP.	**6 - ZERO SEQ. ADMIT.**
	7 - GROUND DIR. COMP.	**7 - ZERO SEQ. ADMIT. ANG.**
	8 - POS. SEQ. DIR. COMP.	
	9 - NEG. SEQ. DIR. COMP.	

0 - LINE DIFFERENTIAL	0 - GENERAL	**0 - MASTER DEVICE**
1 - FUSE FAILURE	1 - LINE IMPEDANCE	**1 - LOCAL ADDRESS**
2 - DEAD LINE DETECTOR	**2 - COMMUNICATIONS**	**2 - REMOTE ADDRESS**
3 - OPEN POLE LOGIC	3 - PHASE DIFFERENTIAL	**3 - GPS SYNCHRONIZATION**
4 - OVERCURRENT	4 - GROUND DIFFERENTIAL	**4 - TGO - TRETURN**
...	5 - NEG. SEQ. DIFFERENTIAL	**5 - MAX. CHANNEL TIME**
	6 - PHASE DIR. COMP.	**6 - MAX. SWITCH TIME**
	7 - GROUND DIR. COMP.	**7 - MAX. JITTER**
	8 - POS. SEQ. DIR. COMP.	**8 - ER. FR SEV. ER SEC**
	9 - NEG. SEQ. DIR. COMP.	**9 - SEV. ER. SEC. UNAV**
		10 - NON-ER. SEC. AVAIL

0 - LINE DIFFERENTIAL	0 - GENERAL	**0 - ENABLE**
1 - FUSE FAILURE	1 - LINE IMPEDANCE	**1 - SENSITIVITY**
2 - DEAD LINE DETECTOR	2 - COMMUNICATIONS	**2 - SENSITIVITY COF**
3 - OPEN POLE LOGIC	**3 - PHASE DIFFERENTIAL**	**3 - SLOPE 1**
4 - OVERCURRENT	4 - GROUND DIFFERENTIAL	**4 - SLOPE 1 START**
...	5 - NEG. SEQ. DIFFERENTIAL	**5 - SLOPE 2**
	6 - PHASE DIR. COMP.	**6 - SLOPE 2 START**
	7 - GROUND DIR. COMP.	**7 - TIME DELAY**
	8 - POS. SEQ. DIR. COMP.	
	9 - NEG. SEQ. DIR. COMP.	

0 - LINE DIFFERENTIAL	0 - GENERAL	**0 - ENABLE**
1 - FUSE FAILURE	1 - LINE IMPEDANCE	**1 - SENSITIVITY**
2 - DEAD LINE DETECTOR	2 - COMMUNICATIONS	**2 - SENSITIVITY COF**
3 - OPEN POLE LOGIC	3 - PHASE DIFFERENTIAL	**3 - SLOPE 1**
4 - OVERCURRENT	**4 - GROUND DIFFERENTIAL**	**4 - SLOPE 1 START**
...	5 - NEG. SEQ. DIFFERENTIAL	**5 - SLOPE 2**
	6 - PHASE DIR. COMP.	**6 - SLOPE 2 START**
	7 - GROUND DIR. COMP.	**7 - TIME DELAY**
	8 - POS. SEQ. DIR. COMP.	
	9 - NEG. SEQ. DIR. COMP.	

0 - LINE DIFFERENTIAL	0 - GENERAL	**0 - ENABLE**
1 - FUSE FAILURE	1 - LINE IMPEDANCE	**1 - SENSITIVITY**
2 - DEAD LINE DETECTOR	2 - COMMUNICATIONS	**2 - SENSITIVITY COF**
3 - OPEN POLE LOGIC	3 - PHASE DIFFERENTIAL	**3 - SLOPE 1**
4 - OVERCURRENT	4 - GROUND DIFFERENTIAL	**4 - SLOPE 1 START**
...	**5 - NEG. SEQ. DIFFERENTIAL**	**5 - SLOPE 2**
	6 - PHASE DIR. COMP.	**6 - SLOPE 2 START**
	7 - GROUND DIR. COMP.	**7 - TIME DELAY**
	8 - POS. SEQ. DIR. COMP.	
	9 - NEG. SEQ. DIR. COMP.	

3.1.11 Digital Inputs and Events of the Differential Units

Table 3.1-1: Digital Inputs and Events of the Differential Units

Name	Description	Functions
REP_DIF_CH1	Reset Command for Differential Channel 1 Error Counter	Activation of this input resets the Erroneous Seconds Counters of the Differential Protection Channel 1.
REP_DIF_CH2	Reset Command for Differential Channel 2 Error Counter	Activation of this input resets the Erroneous Seconds Counters of the Differential Protection Channel 2.
ENBL_87P	Phase Differential Unit Enable Input	Activation of this input puts the unit into service. It can be assigned to digital inputs by level or to commands from the communications protocol or from the HMI. The default value of this logic input signals is a "1."
ENBL_87N	Ground Differential Unit Enable Input	
ENBL_87Q	Negative Sequence Differential Unit Enable Input	
ENBL_CAPCOM	Capacitive Current Compensation Enable Input (DLX-B)	
INBLK_87A	Phase A Differential Unit Trip Blocking Input	Activation of the input before the trip is generated prevents the unit from operating. If activated after the trip, it resets.
INBLK_87B	Phase B Differential Unit Trip Blocking Input	
INBLK_87C	Phase C Differential Unit Trip Blocking Input	
INBLK_87N	Ground Differential Unit Trip Blocking Input	
INBLK_87Q	Negative Sequence Differential Unit Trip Blocking Input	
IN_VIR_01	Virtual Digital Input 1	Indicates the activation of the corresponding Virtual Digital Input.
IN_VIR_02	Virtual Digital Input 2	
IN_VIR_03	Virtual Digital Input 3	
IN_VIR_04	Virtual Digital Input 4	
IN_VIR_05	Virtual Digital Input 5	
IN_VIR_06	Virtual Digital Input 6	
IN_VIR_07	Virtual Digital Input 7	
IN_VIR_08	Virtual Digital Input 8	
IN_VIR_09	Virtual Digital Input 9	
IN_VIR_10	Virtual Digital Input 10	
IN_VIR_11	Virtual Digital Input 11	
IN_VIR_12	Virtual Digital Input 12	
IN_VIR_13	Virtual Digital Input 13	
IN_VIR_14	Virtual Digital Input 14	

3.1.12 Digital Outputs and Events of the Differential Units

Table 3.1-2: Digital Outputs and Events of the Differential Units		
Name	**Description**	**Function**
ADDR_MIS	Local and Remote Addresses Mismatch	Remote address setting does not match the address received.
EX_CH_TIME	Excessive Channel Time	Calculated channel time exceeds the Maximum channel time setting.
CO_CH_TIME	Constant Channel Time	Channel time variation must be less than Maximum channel time variation setting during Maximum channel switch time setting.
DL_CH1_OPEN	Differential Channel 1 Open	Channel 1 open.
DL_CH1_INUSE	Differential Channel 1 in Use	Channel 1 in use.
DL_CH1_UNAVLB	Differential Channel 1 Unavailable	Channel 1 not available.
DL_CH2_OPEN	Differential Channel 2 Open	Channel 2 open.
DL_CH2_INUSE	Differential Channel 2 in Use	Channel 2 in use.
DL_CH2_UNAVLB	Differential Channel 2 Unavailable	Channel 2 not available.
HDLC1_FCOMS	Communication Failure on HDLC Port 1	Failure in Differential Port 1.
HDLC2_FCOMS	Communication Failure on HDLC Port 2	Failure in Differential Port 2.
CH1_FAIL	Differential Protection Channel 1 Communication Failure	Failure in the corresponding Channel.
CH2_FAIL	Differential Protection Channel 2 Communication Failure	
UDL_READY	Differential Unit Ready	Differential Unit ready to operate.
SYNC_PROC	Differential Unit in Synchronization Process	Differential unit in Synchronization process.
DIF_TESTMODE	Differential Unit Test Mode	Differential Unit in Test Mode.
PU_87A	Phase A Differential Unit Pick-up	Pickup of the Differential Units and start of the time count.
PU_87B	Phase B Differential Unit Pick-up	
PU_87C	Phase C Differential Unit Pick-up	
PU_87N	Ground Differential Unit Pick-up	
PU_87Q	Negative Sequence Differential Unit Pick-up	
TRIP_87A	Phase A Differential Unit Trip	Trip of the Differential Units.
TRIP_87B	Phase B Differential Unit Trip	
TRIP_87C	Phase C Differential Unit Trip	
TRIP_87PH	Phase Differential Unit Trip	
TRIP_87N	Ground Differential Unit Trip	
TRIP_87Q	Negative Sequence Differential Unit Trip	

Table 3.1-2: Digital Outputs and Events of the Differential Units		
Name	**Description**	**Function**
87P_ENBLD	Phase Differential Unit Enabled	Indication of enabled or disabled status of the units.
87N_ENBLD	Ground Differential Unit Enabled	
87Q_ENBLD	Negative Sequence Differential Unit Enabled	
CAPCOM_ENBLD	Capacitive Current Compensation Enabled (DLX-B)	
COF_SENS	Close-onto-Fault Sensitivity	Activation when Close-onto-Fault Sensitivity is used.
DEC_IDIF	Differential Current Decrease	Indicates an abrupt decrease of the differential current due to a fault trip. It generates a blocking to avoid differential unit transitory trips.
OUT_VIR_01	Virtual Digital Output 1	Activation of the corresponding Virtual Digital Output.
OUT_VIR_02	Virtual Digital Output 2	
OUT_VIR_03	Virtual Digital Output 3	
OUT_VIR_04	Virtual Digital Output 4	
OUT_VIR_05	Virtual Digital Output 5	
OUT_VIR_06	Virtual Digital Output 6	
OUT_VIR_07	Virtual Digital Output 7	
OUT_VIR_08	Virtual Digital Output 8	
OUT_VIR_09	Virtual Digital Output 9	
OUT_VIR_10	Virtual Digital Output 10	
OUT_VIR_11	Virtual Digital Output 11	
OUT_VIR_12	Virtual Digital Output 12	
OUT_VIR_13	Virtual Digital Output 13	
OUT_VIR_14	Virtual Digital Output 14	
REP_DIF_CH1	Reset Command for Differential Channel 1 Error Counter	The same as for the Digital Inputs.
REP_DIF_CH2	Reset Command for Differential Channel 2 Error Counter	
ENBL_87P	Phase Differential Unit Enable Input	
ENBL_87N	Ground Differential Unit Enable Input	
ENBL_87Q	Negative Sequence Differential Unit Enable Input	
ENBL_CAPCOM	Capacitive Current Compensation Enable Input (DLX-B)	

Table 3.1-2: Digital Outputs and Events of the Differential Units		
Name	**Description**	**Function**
INBLK_87A	Phase A Differential Unit Trip Blocking Input	The same as for the Digital Inputs.
INBLK_87B	Phase B Differential Unit Trip Blocking Input	
INBLK_87C	Phase C Differential Unit Trip Blocking Input	
INBLK_87N	Ground Differential Unit Trip Blocking Input	
INBLK_87Q	Negative Sequence Differential Unit Trip Blocking Input	
IN_VIR_01	Virtual Digital Input 1	The same as for the Digital Inputs.
IN_VIR_02	Virtual Digital Input 2	
IN_VIR_03	Virtual Digital Input 3	
IN_VIR_04	Virtual Digital Input 4	
IN_VIR_05	Virtual Digital Input 5	
IN_VIR_06	Virtual Digital Input 6	
IN_VIR_07	Virtual Digital Input 7	
IN_VIR_08	Virtual Digital Input 8	
IN_VIR_09	Virtual Digital Input 9	
IN_VIR_10	Virtual Digital Input 10	
IN_VIR_11	Virtual Digital Input 11	
IN_VIR_12	Virtual Digital Input 12	
IN_VIR_13	Virtual Digital Input 13	
IN_VIR_14	Virtual Digital Input 14	

3.1.13 Differential Module Magnitudes

Table 3.1-3: Differential Module Magnitudes		
Name	**Description**	**Function**
IncT	Time Difference between Local and Remote Clocks (Master and Slave)	ms
IncT Med	Averaged Time Difference between Local and Remote Clocks (master and slave)	ms
IncT M Cong	Stored log for Averaged Time Difference between Local and Remote Clocks (master and slave)	ms
Corr IncT	Corrected Time Difference used during Communication Synchronization. The correction is calculated during GPS synchronization.	ms
T Canal 1	Channel 1 Propagation Time	s
T Canal 2	Channel 2 Propagation Time	s
Tseg	Time between two PPS	s
Tseg Med	Time between two PPS Averaged	s
ERR SEC 1	Number of Errored Seconds on Channel 1	
ERR SEC 1	Number of Errored Seconds on Channel 2	
SEV ERR SEC 1	Number of Severe Errored Seconds on Channel 1	
SEV ERR SEC 2	Number of Severe Errored Seconds on Channel 2	

3.1.14 Differential Units Test

3.1.14.a Dual Relay Test

To carry out the test, both relays must be connected, one to each other. Connect port DP1 of the first relay to port DP1 of the second relay (TX to RX and RX to TX). Do the same with ports DP2.

In one of the relays, which will be referred to as DLX-2, the settings in the table below shall be changed according to the values shown. The rest of the settings will take the default value.

Table 3.1-4: Settings for the Dual Relay Test

DLX-2 relay settings	Value	
Master Relay	YES	
Local Address	0	
Remote Address	1	
DLX-1 relay settings	**Value IN=1A**	**Value IN=5A**
Directional Comparison Blocking	NO	NO
Master Relay	NO	NO
Local Address	1	1
Remote Address	0	0
Sensitivity (For Phase, Ground and Negative Sequence Differential Elements)	0.1	0.5
First Slope Start (for Phase, Ground and Negative Sequence Differential Elements)	0.2	1
Second Slope Start (for Phase, Ground and Negative Sequence Differential Elements)	1	5
First Slope (for Phase, Ground and Negative Sequence Differential Elements)	25%	25%
Second Slope (for Phase, Ground and Negative Sequence Differential Elements)	100%	100%
Supervision by Fault Detector	NO	NO

Default values shall be taken for the rest of settings.

Note 1: for the test described here, synchronization by communications has been selected, through the ping-pong method in section 3.1.1.a. However, the same test may be carried out with synchronization by GPS and connecting an IRIG-B signal to the corresponding port in both relays.

Note 2: Most of automatic tests carried out by injection relays to test the performance of a differential restraint characteristic, apply two currents with a phase difference of 180º. This test would continuously activate external fault signals generated by directional comparison elements, hence, if the directional comparison blocking setting is set to YES (see section 3.4), no differential elements could trip. Faults injected by test relays correspond to internal faults (since they generate differential current) with outfeed effect. The phase directional comparison element would not detect an external fault condition if the adequate current threshold is selected. Nevertheless, positive sequence, negative sequence and ground directional comparison elements would continuously activate the external fault signal. This would not take place if the test relay injects a pre-fault value that matches the fault current (that which generates pure fault currents in both line ends practically in phase). If pre-fault is not injected, or if an unreal pre-fault value, for internal fault, with regard to the fault value is injected, the differential element directional comparison blocking must be disabled. To prevent problems, the directional comparison blocking setting has been set to NO.

Note 3: supervision by fault detector will be set to NO whenever a static test, without fast current transients, is required.

- **Phase Differential Test**

The trip mask of the phase differential element shall be enabled, keeping the corresponding masks of the ground and negative sequence differential elements disabled.

Until the Start of the First Restraint Slope

The restraint current 1 will be used for the test, (I1+I2-Id)/2, with phase X (X=A, B, C).

The values shown in table corresponding to the beginning of the test shall be injected. IA_{DLX-1} shall be increased slowly, until the differential element of phase X trips.

Table 3.1-5: Phase Differential Test. Start (Dual Relay Test)

Currents at the beginning of the test		Element pickup currents		Element reset currents	
Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A
IX-1=0.5 0º IX-2=0.5 180º	IX-1=0.1 0º IX-2=0.1 180º	IX-1=1 0º +- 1% or 20 mA (the greater)	IX-1=0.2 0º +- 1% or 20 mA (the greater)	IX-1=0.9 0º +- 1% or 20 mA (the greater)	IX-1=0.18 0º +- 1% or 20 mA (the greater)

Note: in the tables:

IX-1=IX_{DLX-1}
IX-2=IX_{DLX-2}
(X=A, B, C)

Current values are in Amp (A).

First Restraint Slope

Restraint current 2 shall be used, (I1+I2)/2, with phase X (X=A, B, C).

Set **Type of Restraint Current** to (I1+I2)/2.

The values shown in table corresponding to the beginning of the test shall be injected. IX_{DLX-1} shall be increased slowly and, at the same time, IX_{DLX-2} shall be reduced in the same proportion, until the differential element of phase X trips.

Table 3.1-6:Phase Differential Test. First Slope (Dual Relay Test)

Currents at the beginning of the test		Element pickup currents		Element reset currents	
Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A
IX-1=2 0º IX-2=2 180º	IX-1=0,4 0º IX-2=0,4 180º	IX-1=2,375 0º IX-2=1,625 180º +- 1% or 20 mA (the greater)	IX-1=0,475 0º IX-2=0,325 180º +- 1% or 20 mA (the greater)	IX-1=2,2 0º IX-2=1,8 180º +- 1% or 20 mA (the greater)	IX-1=0,44 0º IX-2=0,36 180º +- 1% or 20 mA (the greater)

Second Restraint Slope

Restraint current 1 shall be used, (I1+I2-Id)/2 with the phase X.

Set **Type of Restraint Current** to (I1+I2-Id)/2.

The values shown in table corresponding to the beginning of the test shall be injected. IA_{DLX-1} shall be increased slowly until the differential element of phase X trips.

Table 3.1-7:Phase Differential Test. Second Slope (Dual Relay Test)

Currents at the beginning of the test		Element pickup currents		Element reset currents	
Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A
IX-1=8 0º IX-2=8 180º	IX-1=2 0º IX-2=2 180º	IX-1=12,5 0º +- 1% or 20 mA (the greater)	IX-1=3,3 0º +- 1% or 20 mA (the greater)	IX-1=8,4 0º +- 1% or 20 mA (the greater)	IX-1=2,08 0º +- 1% or 20 mA (the greater)

- **Ground Differential Element Test**

The trip mask of the ground differential element shall be enabled, keeping phase and negative sequence differential element trip masks disabled.

Until the Start of the First Restraint Slope

Restraint current 1 shall be used, (I1+I2-Id)/2

The values shown in table corresponding to the beginning of the test shall be injected. The three phase currents in the DLX-1 shall be increased slowly until the ground differential element trips.

Table 3.1-8:Ground Differential Element Test. Beginning (Dual Relay Test)

Currents at the beginning of the test		Element pickup currents		Element reset currents	
Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A
IA-1=0,166 0º IB-1=0,166 0º IC-1=0,166 0º IA-2=0,166 180º IB-2=0,166 180º IC-2=0,166 180º	IA-1=0,033 0º IB-1=0,033 0º IC-1=0,033 0º IA-2=0,033 180º IB-2=0,033 180º IC-2=0,033 180º	IA-1=0,333 0º IB-1=0,333 0º IC-1=0,333 0º +- 1% or 20 mA (the greater)	IA-1=0,066 0º IB-1=0,066 0º IC-1=0,066 0º +- 1% or 20 mA (the greater)	IA-1=0,3 0º IB-1=0,3 0º IC-1=0,3 0º +- 1% or 20 mA (the greater)	IA-1=0,06 0º IB-1=0,06 0º IC-1=0,06 0º +- 1% or 20 mA (the greater)

First Restraint Slope

Restraint current 2 shall be used, (I1+I2)/2

Set **Type of Restraint Current** to (I1+I2)/2.

The values shown in table corresponding to the beginning of the test shall be injected. The three phase currents in the DLX-1 shall be increased slowly and, at the same time, the three phase currents will decrease, in the same proportion, in the DLX-2 until the ground differential element trips.

Table 3.1-9:Ground Differential Element Test. First Slope (Dual Relay Test)

Currents at the beginning of the test		Element pickup currents		Element reset currents	
Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A
IA-1=0,666 0º IB-1=0,666 0º IC-1=0,666 0º IA-2=0,666 180º IB-2=0,666 180º IC-2=0,666 180º	IA-1=0,133 0º IB-1=0,133 0º IC-1=0,133 0º IA-2=0,133 180º IB-2=0,133 180º IC-2=0,133 180º	IA-1=0,792 0º IB-1=0,792 0º IC-1=0,792 0º IA-2=0,542 180º IB-2=0,542 180º IC-2=0,542 180º +- 1% or 20 mA (el mayor	IA-1=0,158 0º IB-1=0,158 0º IC-1=0,158 0º IA-2=0,108 180º IB-2=0,108 180º IC-2=0,108 180º +- 1% or 20 mA (the greater)	IA-1=0,733 0º IB-1=0,733 0º IC-1=0,733 0º IA-2=0,6 180º IB-2=0,6 180º IC-2=0,6 180º +- 1% or 20 mA (the greater)	IA-1=0,147 0º IB-1=0,147 0º IC-1=0,147 0º IA-2=0,12 180º IB-2=0,12 180º IC-2=0,12 180º +- 1% or 20 mA (the greater)

Second Restraint Slope

Restraint current 1 shall be used, (I1+I2-Id)/2.

Set **Type of Restraint Current** to (I1+I2-Id)/2.

The values shown in table corresponding to the beginning of the test shall be injected. The three phase currents shall be increased slowly en el DLX-1 until the ground differential element trips.

Table 3.1-10: Ground Differential Element Test. Second Slope (Dual Relay Test)

Currents at the beginning of the test		Element pickup currents		Element reset currents	
Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A
IA-1=2,666 0º IB-1=2,666 0º IC-1=2,666 0º IA-2=2,666 180º IB-2=2,666 180º IC-2=2,666 180º	IA-1=0,666 0º IB-1=0,666 0º IC-1=0,666 0º IA-2=0,666 180º IB-2=0,666 180º IC-2=0,666 180º	IA-1=4,166 0º IB-1=4,166 0º IC-1=4,166 0º +- 1% or 20 mA (the greater)	IA-1=1,1 0º IB-1=1,1 0º IC-1=1,1 0º +- 1% or 20 mA (the greater)	IA-1=2,8 0º IB-1=2,8 0º IC-1=2,8 0º +- 1% or 20 mA (the greater)	IA-1=0,693 0º IB-1=0,693 0º IC-1=0,693 0º +- 1% or 20 mA (the greater)

- **Negative Sequence Differential Test**

The trip mask of the negative sequence differential element shall be enabled, keeping phase and ground differential element trip masks disabled.

Until the Start of the First Restraint Slope

Restraint Current 1 shall be used, (I1+I2-Id)/2.

The values shown in table corresponding to the beginning of the test shall be injected. The three phase currents shall be increased slowly in the DLX-1 until the negative sequence differential element trips.

Table 3.1-11: Negative Sequence Differential Test. Start (Dual relay test)

Currents at the beginning of the test		Element pickup currents		Element reset currents	
Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A
IA-1=0,5 0º IB-1=0,5 120º IC-1=0,5 240º IA-2=0,5 180º IB-2=0,5 300º IC-2=0,5 60º	IA-1=0,1 0º IB-1=0,1 120º IC-1=0,1 240º IA-2=0,1 180º IB-2=0,1 300º IC-2=0,1 60º	IA-1=1 0º IB-1=1 120º IC-1=1 240º +- 1% or 20 mA (the greater)	IA-1=0,2 0º IB-1=0,2 120º IC-1=0,2 240º +- 1% or 20 mA (the greater)	IA-1=0,9 0º IB-1=0,9 120º IC-1=0,9 240º +- 1% or 20 mA (the greater)	IA-1=0,18 0º IB-1=0,18 120º IC-1=0,18 240º +- 1% or 20 mA (the greater)

Note: currents IA, IB and IC injected in this test follow a reverse system of the type ACB, so that IB has a phase lead of 120º instead of 240º and IC has a phase lead of 240º instead of 120º.

First Restraint Slope

Restraint Current 2 shall be used, (I1+I2)/2

Set **Type of Restraint Current** to (I1+I2)/2.

The values shown in table corresponding to the beginning of the test shall be injected. The three phase currents shall be increased slowly in the DLX-1 and, at the same time, the three phase currents will decrease in the DLX-2, in the same proportion, until the negative sequence differential element trips.

Table 3.1-12: Negative Sequence Differential Test. First Slope (Dual relay test)

Currents at the beginning of the test		Element pickup currents		Element reset currents	
Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A
IA-1=2 0º IB-1=2 120º IC-1=2 240º IA-2=2 180º IB-2=2 300º IC-2=2 60º	IA-1=0,4 0º IB-1=0,4 120º IC-1=0,4 240º IA-2=0,4 180º IB-2=0,4 300º IC-2=0,4 60º	IA-1=2,375 0º IB-1=2,375 120º IC-1=2,375 240º IA-2=1,625 180º IB-2=1,625 300º IC-2=1,625 60º +- 1% or 20 mA (the greater)	IA-1=0,475 0º IB-1=0,475 120º IC-1=0,475 240º IA-2=0,325 180º IB-2=0,325 300º IC-2=0,325 60º +- 1% or 20 mA (the greater)	IA-1=2,2 0º IB-1=2,2 120º IC-1=2,2 240º IA-2=1,8 180º IB-2=1,8 300º IC-2=1,8 60º +- 1% or 20 mA (the greater)	IA-1=0,44 0º IB-1=0,44 120º IC-1=0,44 240º IA-2=0,36 180º IB-2=0,36 300º IC-2=0,36 60º +- 1% or 20 mA (the greater)

Second Restraint Slope

Restraint Current 1 shall be used, (I1+I2-Id)/2.

Set **Type of Restraint Current** to (I1+I2-Id)/2.

The values shown in table corresponding to the beginning of the test shall be injected. The three phase currents shall be increased slowly in the DLX-1 until the negative sequence differential element trips.

Table 3.1-13:Negative Sequence Differential Test. Second Slope (Dual Relay Test)

Current at the beginning of the test		Element pickup current		Element reset current	
Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A	Inom=5 A	Inom=1 A
IA-1=6 $_{0°}$ IB-1=6 $_{120°}$ IC-1=6 $_{240°}$ IA-2=6 $_{180°}$ IB-2=6 $_{300°}$ IC-2=6 $_{60°}$	IA-1=1,2 $_{0°}$ IB-1=1,2 $_{120°}$ IC-1=1,2 $_{240°}$ IA-2=1,2 $_{180°}$ IB-2=1,2 $_{300°}$ IC-2=1,2 $_{60°}$	IA-1=8,5 $_{0°}$ IB-1=8,5 $_{120°}$ IC-1=8,5 $_{240°}$ +- 1% or 20 mA (the greater)	IA-1=1,7 $_{0°}$ IB-1=1,7 $_{120°}$ IC-1=1,7 $_{240°}$ +- 1% or 20 mA (the greater)	IA-1=6,4 $_{0°}$ IB-1=6,4 $_{120°}$ IC-1=6,4 $_{240°}$ +- 1% or 20 mA (the greater)	IA-1=1,28 $_{0°}$ IB-1=1,28 $_{120°}$ IC-1=1,28 $_{240°}$ +- 1% or 20 mA (the greater)

3.1.14.b Single Relay Test

If **Test Mode** is set to YES and both ports DP1 and DP2 used by the differential element are connected to each other (TX to RX and RX to TX), the remote currents will become equal to the local currents, so that the differential current will be **2*I** and the restraint current will be: 0 if the first formula, (I1+I2-Id)/2 is used or equal to **I** if the second formula, (I1+I2)/2 is used.

The settings shown in the table shall be used:

Table 3.1-14: Settings for Single Relay Test

Setting	Value
Directional Comparison Blocking	NO
Test Mode	YES
Sensitivity (for Phase, Ground and Negative Sequence Differential Elements)	0.5
First Slope Start (for Phase, Ground and Negative Sequence Differential Elements)	1
Second Slope Start (for Phase, Ground and Negative Sequence Differential Elements)	5
First Slope (for Phase, Ground and Negative Sequence Differential Elements)	25%
Second Slope (for Phase, Ground and Negative Sequence Differential Elements)	100%
Supervision by Fault Detector	NO

- **Phase Differential Element Test**

The values shown in table corresponding to the beginning of the test shall be injected. The current of phase X (X=A, B, C) shall be increased slowly until the differential element of said phase trips.

Table 3.1-15: Phase Differential Test. (Single Relay Test)		
Currents at the beginning of the test	Element pickup currents	Element reset currents
IX=0 0º	IX=0.25 0º +- 1% or 20 mA (the greater)	IX=0.2 0º +- 1% or 20 mA (the greater)

Note: the result does not depend on the formula used for the restraint current.

- **Ground Differential Element Test**

The values shown in table corresponding to the beginning of the test shall be injected. The three phase currents shall be increased slowly until the ground differential element trips.

Table 3.1-16:Ground Differential Element Test. (Single Relay Test)		
Currents at the beginning of the test	Element pickup currents	Element reset currents
IA=0 0º IB=0 0º IC=0 0º	IA=0.083 0º IB=0.083 0º IC=0.083 0º +- 1% or 20 mA (the greater)	IA=0.066 0º IB=0.066 0º IC=0.066 0º +- 1% or 20 mA (the greater)

Note: the result does not depend on the formula used for the restraint current.

- **Negative Sequence Differential Element Test**

The values shown in table corresponding to the beginning of the test shall be injected. The three phase currents shall be increased slowly until the negative sequence differential element trips.

Table 3.1-17:Negative Sequence Differential Element Test. (Single Relay Test)		
Currents at the beginning of the test	Element pickup currents	Element reset currents
IA=0 0º IB=0 120º IC=0 240º	IA=0,25 0º IB=0,25 120º IC=0,25 240º +- 1% or 20 mA (the greater)	IA=0,2 0º IB=0,2 120º IC=0,2 240º +- 1% or 20 mA (the greater)

Note 1: currents IA, IB and IC injected in this test follow a reverse system of the type ACB, so that IB has a phase lead of 120º instead of 240º and IC has a phase lead of 240º instead of 120º.

Note 2: the result does not depend on the formula used for the restraint current.

3.2 Phase Selector

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3.2.1 Operating Principles

The **DLX** is provided with a Phase Selector unit whose function is to determine the type of failure to generate the outputs which include this information. Those outputs will be used by both Ground and Negative Sequence Differential and Directional Comparison units to prevent their operation on faults not involving ground and on three phase faults, respectively. On the other hand, the phase selector outputs are used in the **Single / Three-phase Trip Logic** (**DLX-B** models) to determine the type of tripping to be carried out, in case that this information is not already implicit in started phase differential units: when it is attempted to render single-phase trips through ground or negative sequence overcurrent (if the **87G Single-Phase Trip** and **67G Single-Phase Trip** has been adjusted to **YES** –**DLX-B** models-).

The information on the faulted phases is developed using two algorithms. The first algorithm determines that a three-phase (**3PH_F**) fault is generated if the following conditions are met:

1. **Low Negative Sequence Current component**: presence of negative sequence current not exceeding I2 level setting and a negative sequence current / positive sequence current ratio not exceeding **Factor I2/I1** setting.
2. Low Zero Sequence Current component: presence of negative sequence current not exceeding **I0 Level** setting and a negative sequence current / positive sequence current ratio not exceeding **Factor I0/I1** setting.

The percentages of negative and zero sequence current with respect to the positive sequence current avoid erroneous phase selections due to imbalance deriving from a different degree of saturation presented by the current transformers in case of three-phase faults.

It is important to point out that the three-phase indication is associated with a balanced condition, for which it would also arise in a load situation. The Fault Detector (see 3.3) will be in charge of distinguishing the fault condition of a load.

When the detected fault does not satisfy the conditions to be considered a three-phase fault, the second algorithm will be executed, based on the comparison between positive and negative sequence current magnitudes.

When the fault is not three-phase, but the second condition for three-phase faults is satisfied (low zero sequence current component), the fault involves two phases (**2PH_F**). If the second condition is not met (high zero sequence current component), a ground fault has occurred, which could be single-phase or two phases to ground (**GR_F**).

To determine the phases involved, the angle will be examined:

$$\phi = \arg(Ia2) - \arg(Ia1\_f)$$

Where:

$Ia2$	Phase A negative sequence current component.
$Ia1\_f$	Phase A positive sequence fault current component (without the load component).

The angle diagrams, used to determine the phases under fault as a function of the angle ϕ, are represented in next Figures.

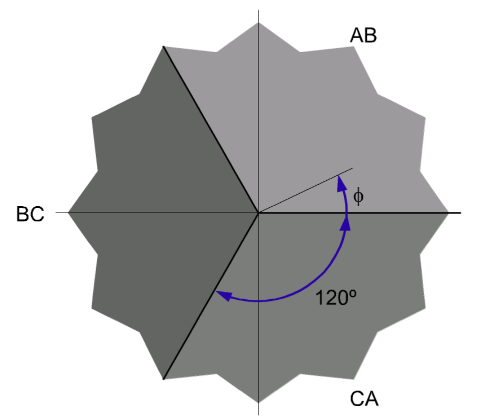

Figure 3.2.1 Two-Phase Fault Angle Diagram.

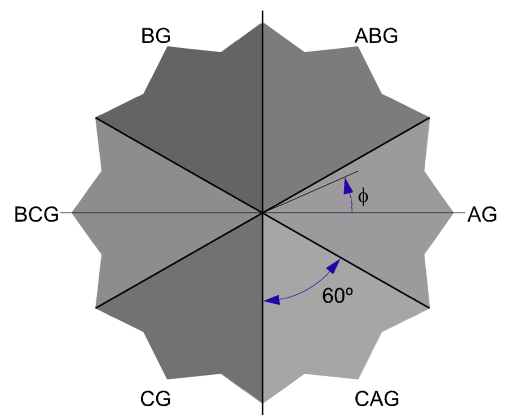

Figure 3.2.2 Single-Phase and Two-Phase- to-Ground Fault Angle Diagram.

The Phase Selector will not operate if the following two conditions are simultaneously complied with:

1. Presence of positive sequence current not above 0.02*In A.
2. Presence of zero sequence current not above 0.05*In A.

3.2.2 Phase Selection upon Faults with Mainly Zero Sequence Current Flow (DLX-B Models)

The presence of power transformers with grounded WYE connected windings, generate, upon weak infeed faults, mainly zero sequence fault current flow. In this case, the positive sequence current can be below 0.02*In A, whereas the zero sequence current will be above the 0.05*In A threshold. If these conditions are met, the Phase Selector will consider it a ground fault but will not determine the faulted phases from the angle between positive and negative sequence currents but based on the activation of three undervoltage elements (one per phase), the pickup level of which is given by the **Weak Infeed Voltage Threshold** setting, also used by the weak infeed logic (see 3.10.7).

3.2.3 Phase Selection with of Open-Pole Conditions

The opening of a breaker pole, detected through the Open-Pole Detector (see 3.5), creates an imbalance which generates negative and zero sequence components in load conditions. In open pole conditions, when a fault occurs, the phase selector will remove prefault currents, to work with fundamental fault currents.

3.2.4 Phase Selector Settings

Phase Selector			
Setting	**Range**	**Step**	**By Default**
I0 Level	0.1 - 5 A	0.01 A	0.25 A
I2 Level	0.1 - 5 A	0.01 A	0.25 A
I0/I1 Constant	5 - 30	0.1	8
I2/I1 Constant	5 - 30	0.1	10

3.2.5 Digital Inputs and Events of the Phase Selector

The phase selector does not present any digital input, not even enable, remaining always in operation.

3.2.6 Digital Outputs and Events for the Final Selection of Fault Type

Table 3.2-1: Digital Outputs and Events for the Final Selection of Fault Type

Name	Description	Function
AG_F	AG Fault	Indication of type of fault.
BG_F	BG Fault	
CG_F	CG Fault	
AB_F	AB Fault	
BC_F	BC Fault	
CA_F	CA Fault	
ABG_F	ABG Fault	
BCG_F	BCG Fault	
CAG_F	CAG Fault	
3PH_F	ABC Fault	
GR_F	Ground Fault	
2PH_F	Two-Phase Fault	
MULTIPH_F	Multi-Phase Fault	

3.3 Fault Detector

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3.3.3 Digital Outputs and Events of the Fault Detector 3.3-4

3.3.1 Operating Principles

DLX relays include a fault detection element for the supervision of current based element operation if **Supervision by Fault Detector** is set to **YES**.

Differential Element tripping is subject to the activation of the Fault Detector. As the latter is only based on local data, said supervision allows for an increased security of differential elements on received frame errors not detected by the CRC.

For Overcurrent Elements, the Fault Detector does not supervise directly the trip signal but, once it is produced, allows the activation of the Breaker Trip signal (activation of **Trip**, **Pole A trip**, **Pole B trip** and **Pole C trip** signals; see Tripping Logic, 3.19). This logic does not apply to Residual Ground Overcurrent elements.

The operation of this element is based on two types of algorithms: Detection of Sequence Current Increments and Detection of Exceeded Sequence Current Levels.

3.3.1.a Detection of Sequence Current Increments

The conditions which activate the Fault Detector are the following:

- An increase in the effective value of the **Zero Sequence Current** with respect to the value of two cycles previously higher than **0.04*In A** (ground fault indicative).
- An increase in the effective value of the **Negative Sequence Current** with respect to the two cycle value previously higher than **0.04*In A** (phase fault indicative).
- A percentual increase in the effective value of the **Positive Sequence Current** with respect to the two-cycle value previously higher than 25% (indicative of any fault).

The activation of the Fault Detector based on previously mentioned increases will remain sealed for the duration of two cycles, given that the comparison is made with magnitudes memorized two cycles previously. Notwithstanding, an additional reset time of 30 ms is included.

3.3.1.b Detection of Exceeded Sequence Current Levels

The following are the conditions which activate the Fault Detector:

- **Ground Fault Output** activation originating from the Phase Selector.
- **Two-Phase Fault Output** activation originating from the Phase Selector.

An open pole condition excludes the **Ground Fault** and **Two Phase Fault** signals from the Fault Detector. Otherwise, this situation would activate the detector as long as the pole remains open.

The above algorithms further need at least one of the following conditions to be met:

- Positive Sequence Current above 0.02*In A.
- Zero Sequence Current above 0.05*In A.

Zero sequence threshold current supervision allows the Fault Detector to be operative upon faults associated to mainly zero sequence current flow.

The activation of the Fault Detector generated by either of the two previously-mentioned algorithms is kept sealed with the activation of any of the **Differential Units** (**PU_87A**, **PU_87B**, **PU_87C**, **PU_87N**, **PU_87Q**), and **Overcurrent** (**PU_IOC_PHn**, **PU_TOC_PHn**, **PU_IOC_Nn**, **PU_TOC_Nn**, **PU_IOC_NSn**, **PU_TOC_NSn**, see overcurrent units).

The operation diagram of the fault detector unit is shown in Figures 3.3.1, 3.3.2 and 3.3.3.

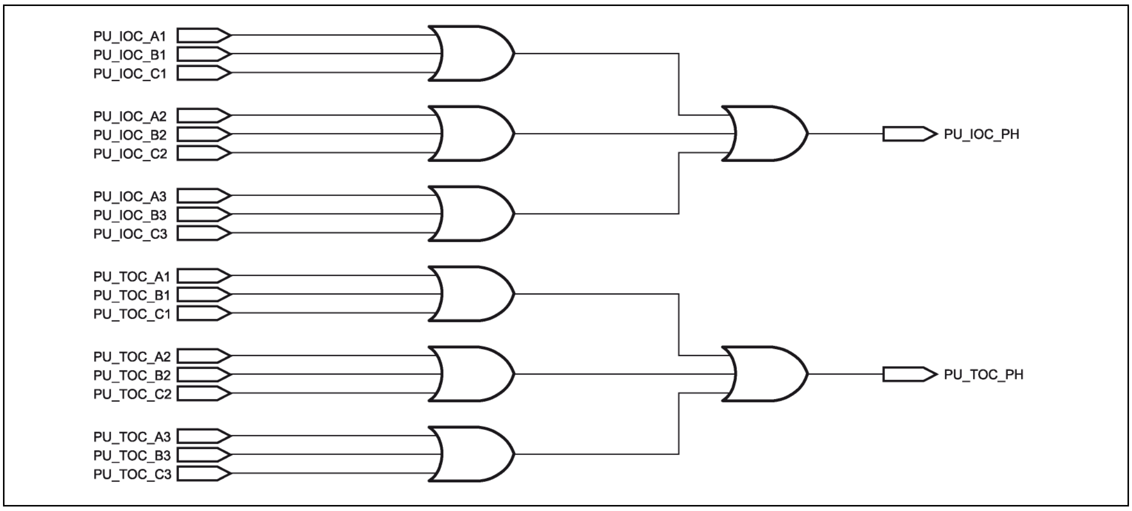

Figure 3.3.1 Activation Logic of Phase Overcurrent Elements Used by the Fault Detector.

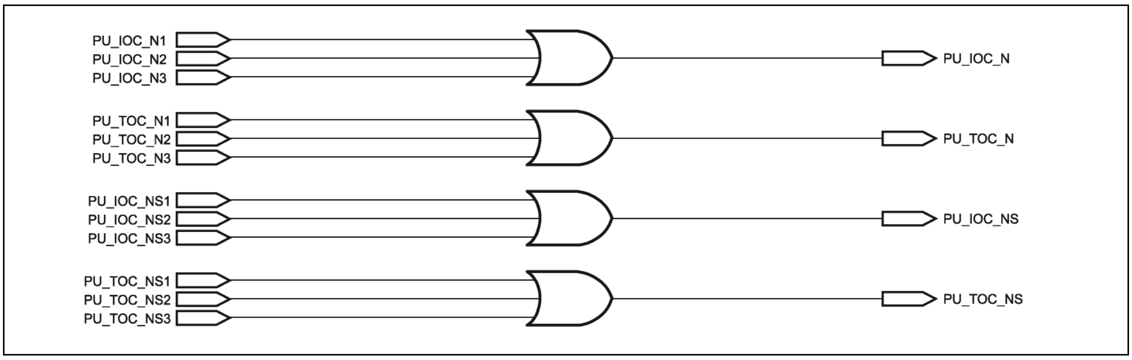

Figure 3.3.2 Activation Logic of Ground and Negative Sequence Overcurrent Elements Used by the Fault Detector.

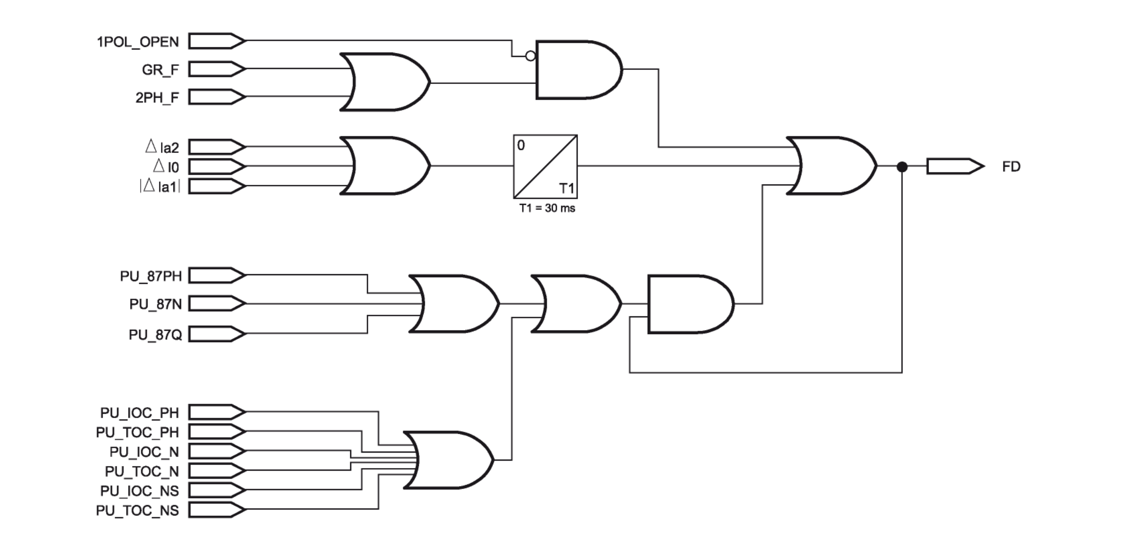

Figure 3.3.3 Fault Detector Block Diagram.

3.3.2 Digital Inputs and Events of the Fault Detector

The fault detector does not present any digital input, not even enable, remaining always in operation.

3.3.3 Digital Outputs and Events of the Fault Detector

Table 3.3-1: Digital Outputs and Events of the Fault Detector		
Name	**Description**	**Function**
FD	Fault Detector Activated	Detection of the existence of a fault.

3.4 Directional Comparison Units

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3.4.1 Principles of Operation

Severe saturation of current transformers may generate, on external faults, differential and restraint current values that cause the Differential Elements to trip, even if they incorporate dual slope percentage characteristics. In order to increase their safety, **DLX** relays are provided with Directional Comparison elements that block the Differential Units on external fault detection. There are four directional comparison elements:

- Phase Directional Comparison element.
- Positive Sequence Directional Comparison element.
- Ground Directional Comparison element.
- Negative Sequence Directional Comparison element.

3.4.2 Phase Directional Comparison Element

This element compares local and remote phase current angles. For external faults, the difference between the phase angles of both currents is 180º, whereas for internal faults, both currents will tend to be in phase. The following algorithm will apply to phase directional comparison elements:

External fault phase X (X=A, B, C):	$90^{\circ} < \arg(IXREM) - \arg(IXLOC) < 270^{\circ}$
Internal fault phase X (X=A, B, C):	$270^{\circ} < \arg(IXREM) - \arg(IXLOC) < 90^{\circ}$

With the above algorithm external fault signals could be activated on internal faults with *outfeed* (faults with high load and weak feed at the load receiving end). In order to prevent the above situation, there exists a minimum threshold for a current to intervene in the directional criterion. Said threshold is defined by **Minimum Current Level** setting, which must be above the maximum possible value of the line current flow.

CT saturation causes a reduction in current magnitude, obtained based on the DFT (Discrete Fourier Transform). If saturation is severe, the RMS value of the current might not exceed the threshold setting. In order to prevent this situation, the current magnitude will be calculated based on the maximum derivative. Sample i current will be defined by the equation:

$I_i = A \cdot \cos(\frac{2\pi i}{N} + \varphi) + B \cdot e^{\lambda i}$, where N represents the number of samples per cycle.

Taking into account that the damping constant λ is very high, the current derivative equation, for sample i, will be approximately:

$$I_i' = A \cdot \frac{2\pi}{N} \cdot \sin(\frac{2\pi i}{N} + \varphi)$$

The maximum value of the current, A, will easily be obtained from the maximum value of the current derivative. When the current is not saturated, the calculated value of A will coincide with the maximum value of the wave. When the current is saturated, the value of the derivative will be greatly increased at CT saturation, which will make the calculated value of A much greater than the maximum value of the actual wave, thus exceeding the minimum threshold. As the maximum value is reached every half cycle, the condition for exceeding the threshold will include a reset time of one cycle.

The exceeded minimum threshold signal will be sent to the remote end via communications. **Phase X Current** (X=A, B, C) **above Minimum Level** will activate just at the time when the maximum value of the current derivative exceeds the corresponding threshold. **Phase X Local Current** (X=A, B, C) **above Minimum Level** will be the same as the above signal but will be only updated at the calculation instants used by the differential module, namely every 4 ms. On the other hand, said signal, associated to the calculation instant n (n=0...24), will not be updated at said instant, but at the time when a remote frame containing that instant number is received; namely, at the time when local and remote signals are aligned. Frames received from the remote relay will include the **Phase X Remote Current** (X=A, B, C) **above Minimum Level.** The time lag between **Phase X Current** (X=A, B, C) **above Minimum Level** and **Phase X Local Current** (X=A, B, C) **above Minimum Level** signals will be the time taken for receiving the remote messages.

The directional comparison element operates with **Phase X Local Current** (X=A, B, C) **above Minimum Level** and **Phase X remote Current** (X=A, B, C) **above Minimum Level** signals.

The Phase Directional Comparison element will only operate when the Fault Detector is active.

The Time Setting of the element affects the internal fault detection signal.

Although the selected angular thresholds allow for important phase errors due to CT saturation (said event always give rise to a phase lead), **DLX** relays include a Saturation Detector (see next section), which allows changing said thresholds, for an even greater tolerance. The resulting algorithm is as follows:

External fault phase X (X=A, B, C):	$90^{o} + \alpha < \arg(\mathrm{IXREM}) - \arg(\mathrm{IXLOC}) < 270^{o} + \alpha$
Internal fault phase X (X=A, B, C):	$270^{o} + \alpha < \arg(\mathrm{IXREM}) - \arg(\mathrm{IXLOC}) < 90^{o} + \alpha$

- α is positive if IXREM is saturated and IXLOC is not saturated (IXREM will lead IXLOC).
- α is negative if IXLOC is saturated and IXREM is not saturated (IXREM will lag IXLOC).
- α is zero if both IXLOC and IXREM are saturated or if neither is saturated.

3.4.3 Saturation Detector

The Saturation Detector is based on the calculation of the derivative of the measured current. Just as CT saturation occurs the derivative suffers a sharp increase. Taking into account that the maximum value of the current derivative is $A \cdot \frac{2\pi}{N}$, where A is the maximum value of the current and N the number of samples per cycle, when $I_i' > k \cdot A \cdot \frac{2\pi}{N}$, k being constant, saturation will be detected. A will be calculated as the largest of two consecutive maximums. The Saturation Detector will only operate when A is greater than the peak value of the local phase nominal current and when the Fault Detector is active. It will include one cycle reset time.

The activated phase X (X=A, B, C) Saturation Detector signal, is sent to the remote end via communications. **Phase X Saturation** (X=A, B, C) will be activated just when the saturation detector algorithm is fulfilled. **Phase X Saturation** (X=A, B, C) **Local Current** will be the same as the above signal but will be only updated at the calculation instants used by the differential module, namely every 4 ms. On the other hand, said signal, associated to the calculation instant n (n=0...24), will not be updated at said instant, but at the time when a remote frame containing that instant number is received; namely, at the time when local and remote signals are aligned. Frames received from the remote relay will include the **Phase X Saturation** (X=A, B, C) **Remote Current** signal**.** The time lag between **Phase X Saturation** (X=A, B, C) and **Phase X Saturation** (X=A, B, C) **Local Current** signals will be the time taken for receiving the remote messages.

The Directional Comparison Element operates with **Phase X Saturation** (X=A, B, C) **Local Current** and **Phase X Saturation** (X=A, B, C) **Remote Current** signals**.**

3.4.4 Positive Sequence Directional Comparison Element

This element compares the phase angles of local and remote pure fault positive sequence currents. In order to obtain the pure fault component of said currents, the relay removes the prefault current, saved two cycles before the activation of the fault detector. The use of pure fault currents removes the influence of the load, which allows for correct directional decisions on internal faults with *outfeed*.

The Positive Sequence Directional Comparison Element algorithm is as follows:

External fault:	$\left\|\arg(\mathrm{I1REM}_{fp}) - \arg(\mathrm{I1LOC}_{fp})\right\| > 70^{\circ}$
Internal fault:	$\left\|\arg(\mathrm{I1REM}_{fp}) - \arg(\mathrm{I1LOC}_{fp})\right\| < 70^{\circ}$

Where $\mathrm{I1REM}_{fp}$ and $\mathrm{I1LOC}_{fp}$ are local and remote pure fault positive sequence currents, respectively, after the prefault component has been removed.

Directional comparison is only carried out when local and remote currents exceed a minimum threshold. On the other hand, the element operates only when the fault detector is active.

The Time setting of the element affects the internal fault signal.

3.4.5 Negative Sequence Directional Comparison Element

This element compares the phase angles of local and remote negative sequence currents. As the negative sequence current is pure fault current, it removes the influence of the load, which allows for correct directional decisions on internal faults with *outfeed*.

In case of open pole (single phase reclose cycle) **DLX-B** relays remove the prefault negative sequence current so as to keep cancelling the effect of the load.

The Negative Sequence Directional Comparison Element algorithm is as follows:

External fault:	$\lvert \arg(\mathrm{I2REM}) - \arg(\mathrm{I2LOC}) \rvert > 70^{\circ}$
Internal fault:	$\lvert \arg(\mathrm{I2REM}) - \arg(\mathrm{I2LOC}) \rvert < 70^{\circ}$

Where I2REM and I2LOC are local and remote negative sequence currents, respectively.

Directional comparison is only carried out when local and remote currents exceed a minimum threshold. On the other hand, the element operates only when the fault detector is active.

The Negative Sequence Directional Comparison Element will only operate when the phase selector does not indicate three phase fault and the three currents do not exceed 2*Inom.

The Time setting of the element affects the internal fault signal.

3.4.6 Ground Directional Comparison Element

This element compares the phase angles of local and remote ground currents. As the ground current is pure fault current, it removes the influence of the load, which allows for correct directional decisions on internal faults with *outfeed*.

In case of Open Pole (Single-Phase Reclose cycle) **DLX-B** relays remove the prefault ground current so as to keep cancelling the effect of the load.

The Ground Directional Comparison Element algorithm is as follows:

External fault:	$\lvert \arg(\mathrm{INREM}) - \arg(\mathrm{INLOC}) \rvert > 70^{\circ}$
Internal fault:	$\lvert \arg(\mathrm{INREM}) - \arg(\mathrm{INLOC}) \rvert < 70^{\circ}$

Where INREM e INLOC are local and remote ground currents, respectively.

Directional comparison is only carried out when local and remote currents exceed a minimum threshold. On the other hand, the element operates only when the fault detector is active.

The Ground Directional Comparison Element will only operate when the Phase Selector indicates ground fault and two or more currents do not exceed 2*Inom provided that, in this latter case, I0/I1<1.25 **(I0 is the zero sequence current and I1 the positive sequence current)**.

The Time setting of the element affects the internal fault signal.

3.4.7 Differential Unit Blocking Logic

If **Directional Comparison Logic** setting is set to **YES**, the phase X (X=A, B, C) Differential Unit and Ground and Negative Sequence Differential units will be blocked:

- Outside the time during which the Close-onto-fault sensitivity is applied (see section 3.1.8): if any Phase X or Positive Sequence Directional Comparison Element indicates external fault, without any element indicating internal fault.
- During the time the Close-onto-fault sensitivity is applied:
    - For three phase faults: if Phase X Directional Comparison Element indicates external fault.
    - For non three phase faults: if any Phase X or Negative Sequence Directional Comparison Element indicates external fault, without any indicating internal fault.

In a Close-onto-Fault situation, there will not be prefault, so the Negative Sequence Comparison Element will be used instead of the Positive Sequence.

In any of the above events, if the Phase Selector indicates ground fault and I0/I1>1,25 **(I0 is the zero sequence current and I1 the positive sequence current)** blocking will occur if any Phase X or Ground Directional Comparison elements indicate external fault and no one indicates internal fault. This latter logic allows correct operation on mainly zero sequence current flow faults for which there is not sufficient positive sequence current flow.

For blocking Ground and Negative Sequence Differential units, the **Phase Directional Comparison** signal must be one OR signal of the three phases.

Note: Most of automatic tests carried out by injection relays to test the performance of a differential restraint characteristic, apply two currents with a phase difference of 180º. This test would continuously activate external fault signals generated by Directional Comparison elements, hence, if the Directional Comparison Blocking setting is set to YES (see section 3.4), no differential elements could trip. Faults injected by test relays correspond to internal faults (since they generate differential current) with outfeed effect. The Phase Directional Comparison Element would not detect an external fault condition if the adequate current threshold is selected. Nevertheless, Positive Sequence, Negative Sequence and Ground Directional Comparison elements would continuously activate the external fault signal. This would not take place if the test relay injects a pre-fault value that matches the fault current (that which generates pure fault currents in both line ends practically in phase). If pre-fault is not injected, or if an unreal pre-fault value, for internal fault, with regard to the fault value is injected, the Differential Unit Directional Comparison Blocking must be disabled.

3.4.8 Directional Comparison Units Settings

Phase Directional Comparison			
Setting	**Range**	**Step**	**By Default**
Enable	YES / NO		YES
Minimum Current Level	0.02*In - 5*In A	0.01 A	1*In A
Time Delay	0 - 300 s	0.01 s	0 s

Positive Sequence Directional Comparison			
Setting	**Range**	**Step**	**By Default**
Enable	YES / NO		YES
Time Delay	0 - 300 s	0.01 s	0 s

Negative Sequence Directional Comparison			
Setting	**Range**	**Step**	**By Default**
Enable	YES / NO		YES
Time Delay	0 - 300 s	0.01 s	0 s

Ground Directional Comparison			
Setting	**Range**	**Step**	**By Default**
Enable	YES / NO		YES
Time Delay	0 - 300 s	0.01 s	0 s

- **Directional Comparison Units: HMI Access (DLX-A Model)**

0 - CONFIGURATION	0 - GENERAL	**0 - LINE DIFFERENTIAL**
1 - OPERATIONS	**1 - PROTECTION**	1 - OPEN POLE LOGIC
2 - ACTIVATE GROUP	2 - RECLOSER	2 - OVERCURRENT
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN PHASE DETECTOR
4 - INFORMATION	...	4 - CT SUPERVISION
		5 - THERMAL IMAGE
		6 - COLD LOAD
		7 - BREAKER FAILURE
		8 - POLE DISCREPANCY
		9 - PHASE SELECTOR
		10 - PROTECTION LOGIC

0 - LINE DIFFERENTIAL	0 - GENERAL	
1 - OPEN POLE LOGIC	1 - COMMUNICATIONS	
2 - OVERCURRENT	2 - PHASE DIFFERENTIAL	
3 - OPEN PHASE DETECTOR	3 - GROUND DIFFERENTIAL	**0 - ENABLE**
4 - CT SUPERVISION	4 - NEG. SEQ. DIFFERENTIAL	**1 - MIN. CURR. LEVEL**
...	**5 - PHASE DIR. COMP.**	**2 - TIME DELAY**
	6 - GROUND DIR. COMP.	
	7 - POS. SEQ. DIR. COMP.	
	8 - NEG. SEQ. DIR. COMP.	

0 - LINE DIFFERENTIAL	0 - GENERAL	
1 - OPEN POLE LOGIC	1 - COMMUNICATIONS	
2 - OVERCURRENT	2 - PHASE DIFFERENTIAL	
3 - OPEN PHASE DETECTOR	3 - GROUND DIFFERENTIAL	
4 - CT SUPERVISION	4 - NEG. SEQ. DIFFERENTIAL	
...	5 - PHASE DIR. COMP.	**0 - ENABLE**
	6 - GROUND DIR. COMP.	**1 - TIME DELAY**
	7 - POS. SEQ. DIR. COMP.	
	8 - NEG. SEQ. DIR. COMP.	

0 - LINE DIFFERENTIAL	0 - GENERAL	
1 - OPEN POLE LOGIC	1 - COMMUNICATIONS	
2 - OVERCURRENT	2 - PHASE DIFFERENTIAL	
3 - OPEN PHASE DETECTOR	3 - GROUND DIFFERENTIAL	
4 - CT SUPERVISION	4 - NEG. SEQ. DIFFERENTIAL	
...	5 - PHASE DIR. COMP.	
	6 - GROUND DIR. COMP.	**0 - ENABLE**
	7 - POS. SEQ. DIR. COMP.	**1 - TIME DELAY**
	8 - NEG. SEQ. DIR. COMP.	

0 - LINE DIFFERENTIAL	0 - GENERAL	
1 - OPEN POLE LOGIC	1 - COMMUNICATIONS	
2 - OVERCURRENT	2 - PHASE DIFFERENTIAL	
3 - OPEN PHASE DETECTOR	3 - GROUND DIFFERENTIAL	
4 - CT SUPERVISION	4 - NEG. SEQ. DIFFERENTIAL	
...	5 - PHASE DIR. COMP.	
	6 - GROUND DIR. COMP.	
	7 - POS. SEQ. DIR. COMP.	**0 - ENABLE**
	8 - NEG. SEQ. DIR. COMP.	**1 - TIME DELAY**

- **Directional Comparison Units: HMI Access (DLX-B Model)**

0 - CONFIGURATION	0 - GENERAL	**0 - LINE DIFFERENTIAL**
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	4 - OVERCURRENT
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - LINE DIFFERENTIAL	0 - GENERAL	
1 - FUSE FAILURE	1 - LINE IMPEDANCE	
2 - DEAD LINE DETECTOR	2 - COMMUNICATIONS	
3 - OPEN POLE LOGIC	3 - PHASE DIFFERENTIAL	
4 - OVERCURRENT	4 - GROUND DIFFERENTIAL	**0 - ENABLE**
...	5 - NEG. SEQ. DIFFERENTIAL	**1 - MIN. CURR. LEVEL**
	6 - PHASE DIR. COMP.	**2 - TIME DELAY**
	7 - GROUND DIR. COMP.	
	8 - POS. SEQ. DIR. COMP.	
	9 - NEG. SEQ. DIR. COMP.	

0 - LINE DIFFERENTIAL	0 - GENERAL	
1 - FUSE FAILURE	1 - LINE IMPEDANCE	
2 - DEAD LINE DETECTOR	2 - COMMUNICATIONS	
3 - OPEN POLE LOGIC	3 - PHASE DIFFERENTIAL	
4 - OVERCURRENT	4 - GROUND DIFFERENTIAL	
...	5 - NEG. SEQ. DIFFERENTIAL	
	6 - PHASE DIR. COMP.	**0 - ENABLE**
	7 - GROUND DIR. COMP.	**1 - TIME DELAY**
	8 - POS. SEQ. DIR. COMP.	
	9 - NEG. SEQ. DIR. COMP.	

0 - LINE DIFFERENTIAL	0 - GENERAL	
1 - FUSE FAILURE	1 - LINE IMPEDANCE	
2 - DEAD LINE DETECTOR	2 - COMMUNICATIONS	
3 - OPEN POLE LOGIC	3 - PHASE DIFFERENTIAL	
4 - OVERCURRENT	4 - GROUND DIFFERENTIAL	
...	5 - NEG. SEQ. DIFFERENTIAL	
	6 - PHASE DIR. COMP.	
	7 - GROUND DIR. COMP.	**0 - ENABLE**
	8 - POS. SEQ. DIR. COMP.	**1 - TIME DELAY**
	9 - NEG. SEQ. DIR. COMP.	

0 - LINE DIFFERENTIAL	0 - GENERAL	
1 - FUSE FAILURE	1 - LINE IMPEDANCE	
2 - DEAD LINE DETECTOR	2 - COMMUNICATIONS	
3 - OPEN POLE LOGIC	3 - PHASE DIFFERENTIAL	
4 - OVERCURRENT	4 - GROUND DIFFERENTIAL	
...	5 - NEG. SEQ. DIFFERENTIAL	
	6 - PHASE DIR. COMP.	
	7 - GROUND DIR. COMP.	
	8 - POS. SEQ. DIR. COMP.	**0 - ENABLE**
	9 - NEG. SEQ. DIR. COMP.	**1 - TIME DELAY**

3.4.9 Digital Inputs of the Directional Comparison Units

Table 3.4-1: Digital Inputs of the Directional Comparison Units

Name	Description	Function
ENBL_CDIR_PH	Phase Directional Comparison Enable Input	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”
ENBL_CDIR_P	Positive Sequence Directional Comparison Enable Input	
ENBL_CDIR_Q	Negative Sequence Directional Comparison Enable Input	
ENBL_CDIR_N	Ground Directional Comparison Enable Input	

3.4.10 Auxiliary Outputs of the Directional Comparison Units

Table 3.4-2: Auxiliary Outputs of the Directional Comparison Units

Name	Description	Function
EXT_CDIR_A	External Fault by Phase A Directional Comparison Unit	External Fault condition in Phase A detected by the Phase Directional Comparison Unit.
EXT_CDIR_B	External Fault by Phase B Directional Comparison Unit	External Fault condition in Phase B detected by the Phase Directional Comparison Unit.
EXT_CDIR_C	External Fault by Phase C Directional Comparison Unit	External Fault condition in Phase C detected by the Phase Directional Comparison Unit.
EXT_CDIR_P	External Fault by Positive Sequence Directional Comparison Unit	External Fault condition detected by the Positive Sequence Directional Comparison Unit.
INT_CDIR_P	Internal Fault by Positive Sequence Directional Comparison Unit	Internal Fault condition detected by the Positive Sequence Directional Comparison Unit.
EXT_CDIR_Q	External Fault by Negative Sequence Directional Comparison Unit	External Fault condition detected by the Negative Sequence Directional Comparison Unit.
INT_CDIR_Q	Internal Fault by Negative Sequence Directional Comparison Unit	Internal Fault condition detected by the Negative Sequence Directional Comparison Unit.
EXT_CDIR_N	External Fault by Ground Directional Comparison Unit	External Fault condition detected by the Ground Directional Comparison Unit.

Table 3.4-2: Auxiliary Outputs of the Directional Comparison Units		
Name	**Description**	**Function**
INT_CDIR_N	Internal Fault by Ground Directional Comparison Unit	Internal Fault condition detected by the Ground Directional Comparison Unit.
INT_MINA	Phase A Current above Minimum Threshold	Phase A current exceeding the minimum threshold for the phase directional comparison.
INT_MINA_LOC	Phase A Local Current above Minimum Threshold	Phase A local current exceeding the minimum threshold for the phase directional comparison. The signal is associated to the calculation instant n of the differential module. It will be updated at the time when a remote frame containing that instant number is received.
INT_MINA_REM	Phase A Remote Current above Minimum Threshold	Phase A remote current exceeding the minimum threshold for the phase directional comparison. The signal is associated to the calculation instant n of the differential module. It will be updated at the time when a remote frame containing that instant number is received.
INT_MINB	Phase B Current above Minimum Threshold	Phase B current exceeding the minimum threshold for the phase directional comparison.
INT_MINB_LOC	Phase B Local Current above Minimum Threshold	Phase B local current exceeding the minimum threshold for the phase directional comparison. The signal is associated to the calculation instant n of the differential module. It will be updated at the time when a remote frame containing that instant number is received.
INT_MINB_REM	Phase B Remote Current above Minimum Threshold	Phase B remote current exceeding the minimum threshold for the phase directional comparison. The signal is associated to the calculation instant n of the differential module. It will be updated at the time when a remote frame containing that instant number is received.

Table 3.4-2: Auxiliary Outputs of the Directional Comparison Units		
Name	**Description**	**Function**
INT_MINC	Phase C Current above Minimum Threshold	Phase C current exceeding the minimum threshold for the phase directional comparison.
INT_MINC_LOC	Phase C Local Current above Minimum Threshold	Phase C local current exceeding the minimum threshold for the phase directional comparison. The signal is associated to the calculation instant n of the differential module. It will be updated at the time when a remote frame containing that instant number is received.
INT_MINC_REM	Phase C Remote Current above Minimum Threshold	Phase C remote current exceeding the minimum threshold for the phase directional comparison. The signal is associated to the calculation instant n of the differential module. It will be updated at the time when a remote frame containing that instant number is received.
SAT_A	Phase A Current Saturation	The CT associated to Phase A local current is saturated.
SAT_A_LOC	Phase A Local Current Saturation	The CT associated to Phase A local current is saturated. The signal is associated to the calculation instant n of the differential module. It will be updated at the time when a remote frame containing that instant number is received.
SAT_A_REM	Phase A Remote Current Saturation	The CT associated to Phase A remote current is saturated. The signal is associated to the calculation instant n of the differential module. It will be updated at the time when a remote frame containing that instant number is received.
SAT_B	Phase B Current Saturation	The CT associated to Phase B local current is saturated.

Table 3.4-2: Auxiliary Outputs of the Directional Comparison Units		
Name	**Description**	**Function**
SAT_B_LOC	Phase B Local Current Saturation	The CT associated to Phase B local current is saturated. The signal is associated to the calculation instant n of the differential module. It will be updated at the time when a remote frame containing that instant number is received.
SAT_B_REM	Phase B Remote Current Saturation	The CT associated to Phase B remote current is saturated. The signal is associated to the calculation instant n of the differential module. It will be updated at the time when a remote frame containing that instant number is received.
SAT_C	Phase C Current Saturation	The CT associated to Phase C local current is saturated.
SAT_C_LOC	Phase C Local Current Saturation	The CT associated to Phase C local current is saturated. The signal is associated to the calculation instant n of the differential module. It will be updated at the time when a remote frame containing that instant number is received.
SAT_C_REM	Phase C Remote Current Saturation	The CT associated to Phase C remote current is saturated. The signal is associated to the calculation instant n of the differential module. It will be updated at the time when a remote frame containing that instant number is received.
CDIR_PH_ENBLD	Phase Directional Comparison Unit Enabled	Indication of enabled or disabled status of the unit.
CDIR_P_ENBLD	Positive Sequence Directional Comparison Unit Enabled	
CDIR_Q_ENBLD	Negative Sequence Directional Comparison Unit Enabled	
CDIR_N_ENBLD	Ground Directional Comparison Unit Enabled	
ENBL_CDIR_PH	Phase Directional Comparison Enable Input	The same as for the digital input.
ENBL_CDIR_P	Positive Sequence Directional Comparison Enable Input	
ENBL_CDIR_Q	Negative Sequence Directional Comparison Enable Input	
ENBL_CDIR_N	Ground Directional Comparison Enable Input	

3.5 Open Pole Detector

3.5.1 Operating Principles 3.5-2
3.5.2 Open Pole Detector Settings 3.5-4
3.5.3 Digital Inputs and Events of the Open Pole Detector 3.5-6
3.5.4 Digital Outputs and Events of the Open Pole Detector 3.5-6

3.5.1 Operating Principles

This unit detects the opening of any pole of the breaker, generating the corresponding outputs (**A Pole Open**, **B Pole Open** and **C Pole Open**), based not only on the condition of the breaker position contacts but also on the output of the three undercurrent detectors, one for each pole, whose levels are given by the following adjustments: **A Pole Open Current Level**, **B Pole Open Current Level** and **C Pole Open Current Level**. With the aperture indication outputs of each pole, the open pole detector also generates the following outputs: **One Open Pole**, **Three Open Poles** or **Any Open Pole**.

The outputs of this unit are used by other units which carry out modifications in the operating logic to adapt to the new situation which causes the opening of any pole of the breaker.

The Open Pole Detector can operate based on two operating logics, exclusive within themselves, each of which can be selected through the **Number of Inputs for Breaker Position** setting. If this setting takes the value **3 Inputs**, the operating logic will be the following:

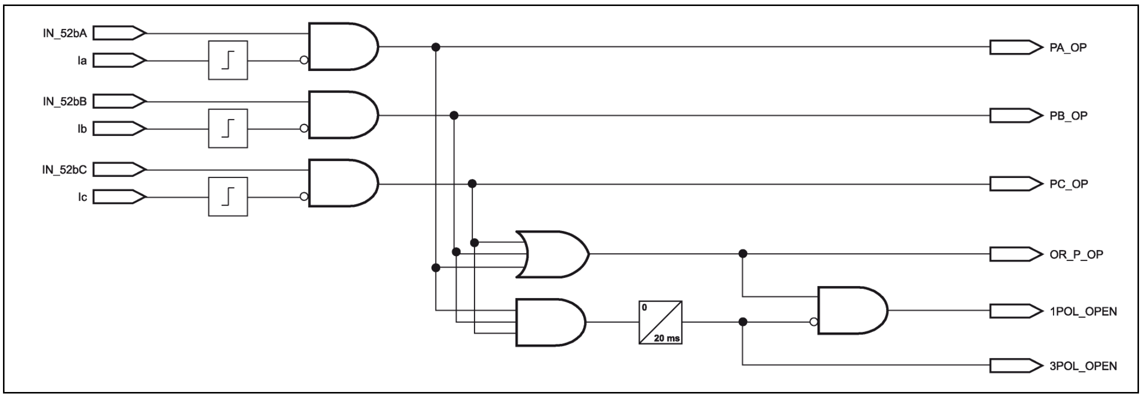

Figure 3.5.1 Logic Diagram of the Open Pole Detector.

IN_52bA, **IN_52bB** e **IN_52bC** inputs are designed to receive breaker **52b** normally closed contact state. However, using programmable logic, said logic inputs could receive breaker **52a** contact (use operator NOT) or both **52b** and **52a** contacts (use operators NOT and AND) state.

The reset time of 20 ms associated with the **Three Pole Open** (**3POL_OPEN**) signal will be used to avoid transient activation of the **One Pole Open** (**1POL_OPEN**) signal in case of imbalances which arise in a three-phase reclose.

If the **Number of Inputs for Breaker Position** setting takes the value **2 Inputs**, the operating logic used becomes the following:

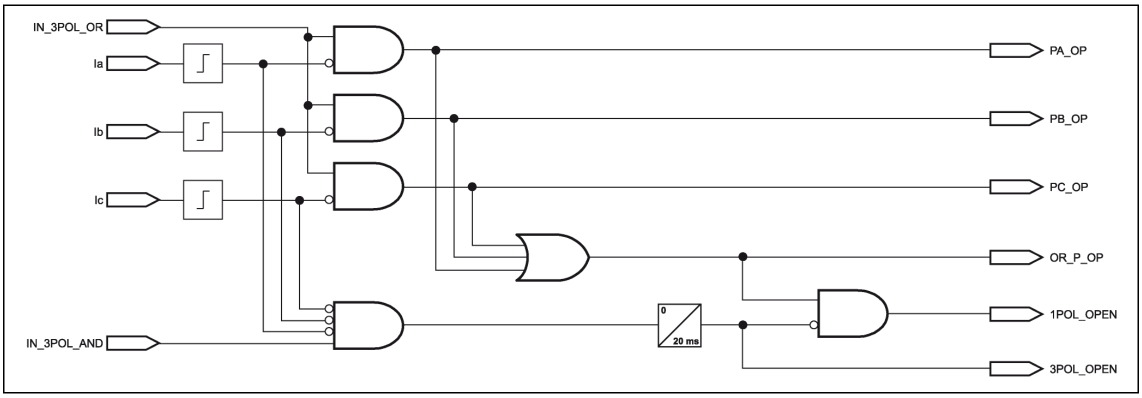

Figure 3.5.2 Logic Diagram of the Open Pole Detector.

This logic allows using one less input than the logic above. Inputs **IN_3POL_OR** and **IN_3POL_AND** are designed to receive one **OR** and one **AND,** respectively, from the breaker **52b** normally closed contacts. However, using programmable logic, one OR and one AND from the **52 a** normally open contacts or both **52b** and **52a** contacts can also be assigned.

The reset time of 20 ms associated with the **Three Pole Open** (**3POL_OPEN**) signal is used, as in the previous logic, to avoid transient activation of the **One Pole Open** (**1POL_OPEN**) signal in case of imbalances which occur in a three-phase reclose.

The outputs of the Open Pole Detector are used by the following units or logics: Phase Selector, Fault Detector, Differential Units, Directional Comparison Units, Ground and Negative Sequence Overcurrent Units, Fuse Failure Detector and Recloser.

3.5.2 Open Pole Detector Settings

Open Pole Detector			
Setting	**Range**	**Step**	**By default**
Number of Inputs for Breaker Position	3 / 2		3
Phase A Current Level	(0.04 - 0.8) In A	0.01 A	0.04 In
Phase B Current Level	(0.04 - 0.8) In A	0.01 A	0.04 In
Phase C Current Level	(0.04 - 0.8) In A	0.01 A	0.04 In

- **Open Pole Detector: HMI Access (DLX-A Model)**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	**1 - OPEN POLE LOGIC**
2 - ACTIVATE GROUP	2 - RECLOSER	2 - OVERCURRENT
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN PHASE DETECTOR
4 - INFORMATION	...	4 - CT SUPERVISION
		5 - THERMAL IMAGE
		6 - COLD LOAD
		7 - BREAKER FAILURE
		8 - POLE DISCREPANCY
		9 - PHASE SELECTOR
		10 - PROTECTION LOGIC

0 - GENERAL	0 - LINE DIFFERENTIAL	**0 - OPEN POLE SELECTION**
1 - PROTECTION	**1 - OPEN POLE LOGIC**	**1 - A POLE OPEN CURRENT**
2 - RECLOSER	2 - OVERCURRENT	**2 - B POLE OPEN CURRENT**
3 - LOGIC	3 - OPEN PHASE DETECTOR	**3 - C POLE OPEN CURRENT**
...	...	

- **Open Pole Detector: HMI Access (DLX-B Model)**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	**3 - OPEN POLE LOGIC**
4 - INFORMATION	...	4 - OVERCURRENT
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - GENERAL	0 - LINE DIFFERENTIAL	**0 - OPEN POLE SELECTION**
1 - PROTECTION	1 - FUSE FAILURE	**1 - BRKS TO SUPERVISE**
2 - RECLOSER	2 - DEAD LINE DETECTOR	**2 - A POLE OPEN CURRENT**
3 - LOGIC	**3 - OPEN POLE LOGIC**	**3 - B POLE OPEN CURRENT**
...	...	**4 - C POLE OPEN CURRENT**

3.5.3 Digital Inputs and Events of the Open Pole Detector

Table 3.5-1: Digital Inputs and Events of the Open Pole Detector

Name	Description	Function
IN_52bA	Open A Pole Position Input	Activation of this input indicates that 52b contact of A pole position of the breaker is closed.
IN_52bB	Open B Pole Position Input	Activation of this input indicates that 52b contact of B pole position of the breaker is closed.
IN_52bC	Open C Pole Position Input	Activation of this input indicates that 52b contact of C pole position of the breaker is closed.
IN_3POL_AND	Open Three Pole Input	The activation of this input indicates that the three 52b contacts of the pole position of the breaker are closed.
IN_3POL_OR	Any Pole Open Input	The activation of this input indicates that any 52b contact of the pole position of the breaker is closed.

3.5.4 Digital Outputs and Events of the Open Pole Detector

Table 3.5-2: Digital Outputs and Events of the Open Pole Detector

Name	Description	Function
PA_OP	Open A Pole	Open (A / B / C) pole indication
PB_OP	Open B Pole	
PC_OP	Open C Pole	
OR_P_OP	Any Pole Open	Any pole open indication.
1POL_OPEN	One Pole Open	One pole open indication. It is also activated when 2 poles open.
3POL_OPEN	Three Poles Open	Three poles open indication.
IN_52bA	Open A Pole Position Input	The same as for the digital inputs.
IN_52bB	Open B Pole Position Input	
IN_52bC	Open C Pole Position Input	
IN_3POL_AND	Open Three Pole Input	The same as for the digital inputs.
IN_3POL_OR	Any Pole Open Input	The same as for the digital inputs.

3.6 VT Fuse Failure Detector

3.6.1 Operating Principles 3.6-2
3.6.2 VT Fuse Failure Detector Settings 3.6-3
3.6.3 Digital Inputs and Events of the VT Fuse Failure Detector 3.6-5
3.6.4 Digital Outputs and Events of the VT Fuse Failure Detector 3.6-5

3.6.1 Operating Principles

When any fuse in the secondary circuit of the transformer is blown, the corresponding voltage input of the relay is lost or, which is the same, said voltage value is zero. Thus, voltage based elements can lead to wrong operations.

DLX-B Models include a VT Fuse Failure Detector that detects the fuse failure condition when one of the three phase voltages drops below 30 V. On not involving this phenomenon at the currents, there will not be a fault detection, for which the output of this detector (**FD**) is used (see 3.3, Fault Detector) as discriminator.

The opening of any pole of the breaker will generate a fuse failure condition if the voltage transformer is on the line side, for which the output of **Any Open Pole** (**OR_P_OP**) originating from the **Open Pole Detector** blocks the activation of the Fuse Failure detector.

On the other hand, the Fuse Failure unit is disabled if the value of the positive sequence current is below 0.05*In A.

VT Fuse Failure Detection operation is shown in Figure 3.6.1.

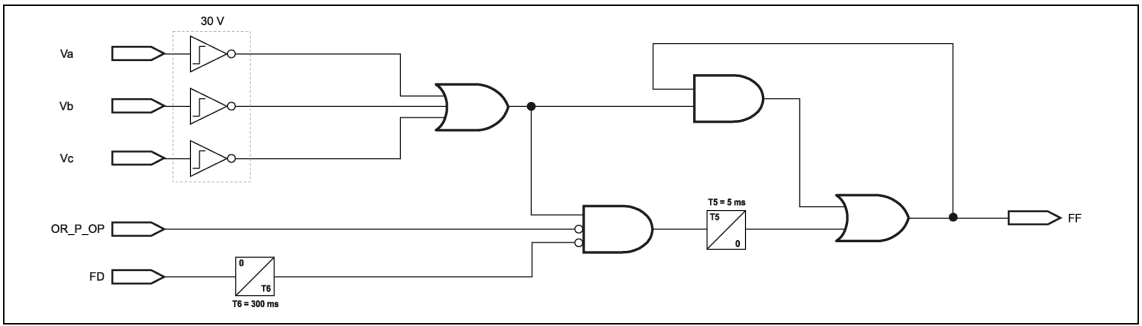

Figure 3.6.1 VT Fuse Failure Detector Block Diagram.

The undervoltage detectors pickup when the voltage is less than 95% of 30 V and reset when it is higher than 30 V.

The output of the Fuse Failure unit will generate **Blocking Due to Fuse Failure** (**BLK_FF**) output if **Blocking Due to Fuse Failure** is set at **YES**. This last output will always block the activation of all the voltage units and may block the activation of other units based on the voltage measurement, such as Weak Infeed logic (See 3.10, Protection Schemes for Overcurrent Elements) or Synchronism Unit, if the corresponding blocking settings are enabled.

The **Fuse Failure** (**IN_FF**) digital input, originating from the contact position of a voltage thermalmagnetic circuit breaker, is another possibility which exists to detect the fuse failure condition. The activation of this input will always generate **Blocking Due to Fuse Failure** output, no matters on the enable and/or blocking adjustments of the Fuse Failure unit. The activation of the **Fuse Failure** digital input presents a fall time adjustment (**Fuse Failure Input Time**), in order to maintain the blocking of the units on which acting during the voltage reset transient.

The logic scheme encompasses the two possibilities of blocking due to fuse failure:

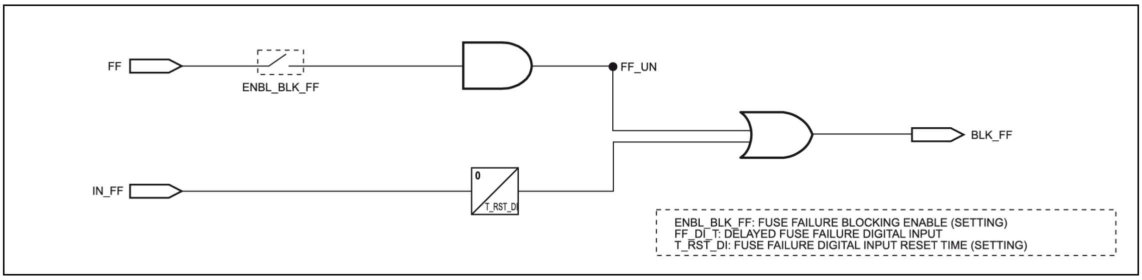

Figure 3.6.2 Logic Diagram of Blocking Due to Fuse Failure.

When a fuse failure condition arises, the Directional Units, supervisors of the Overcurrent Units without **Torque Control** setting at **NO**, they do not have the necessary voltage to be polarized, for which they cannot act if there is a failure in this situation. In order to have an emergency non-directional overcurrent element, provided one does not already exist, the Directional Units present the **Blocking Due to Lack of Polarization** setting. If this adjustment is set at **NO**, when the necessary voltage to polarize these is not available, they go on to issue actuation permission to the overcurrent units on which they depend, consequently converting these into non-directional.

3.6.2 VT Fuse Failure Detector Settings

VT Fuse Failure Detector			
Setting	**Range**	**Step**	**By default**
Enable	YES / NO		
Blocking Enable	YES / NO		
Blocking Reset Time	0 - 1000 ms	50 ms	

- **VT Fuse Failure Detector: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	**1 - FUSE FAILURE**
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	4 - OVERCURRENT
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - GENERAL	0 - LINE DIFFERENTIAL	**0 - FF DET ENABLE**
1 - PROTECTION	**1 - FUSE FAILURE**	**1 - FF BLOCK ENABLE**
2 - RECLOSER	2 - DEAD LINE DETECTOR	**2 - FF INPUT DO DLY**
3 - LOGIC	3 - OPEN POLE LOGIC	
...	...	

3.6.3 Digital Inputs and Events of the VT Fuse Failure Detector

Table 3.6-1: Digital Inputs and Events of the VT Fuse Failure Detector		
Name	**Description**	**Function**
ENBL_FF	VT Fuse Failure Detector Enable Input	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a "1."
IN_FF	VT Fuse Failure Detector Input	The activation of this input directly generates the blocking output due to fuse failure.

3.6.4 Digital Outputs and Events of the VT Fuse Failure Detector

Table 3.6-2: Digital Outputs and Events of the VT Fuse Failure Detector		
Name	**Description**	**Function**
FF	VT Fuse Failure Detector Activated	Output of the VT fuse failure detector.
FF_UN	Fuse Failure Unit Blocking	Blocking output due to fuse failure condition detected by the unit itself.
BLK_FF	Fuse Failure Blocking	Blocking output due to fuse failure condition (detected by the unit itself or by the digital input).
FF_ENBLD	VT Fuse Failure Detector Enabled	Indication of enabled or disabled status of the unit.
ENBL_FF	VT Fuse Failure Detector Enable Input	The same as for the digital input.
IN_FF	VT Fuse Failure Detector Input	The same as for the digital input.

3.7 Dead Line Detector

3.7.1 Operating Principles 3.7-2
3.7.2 Dead Line Detector Settings 3.7-3
3.7.3 Digital Inputs and Events of the Dead Line Detector 3.7-4
3.7.4 Digital Outputs and Events of the Dead Line Detector 3.7-4

3.7.1 Operating Principles

DLX-B relays incorporate a Dead Line detection element to detect deenergized line condition with no need for supervising any physical digital input. This is based on the operation of one undercurrent and one undervoltage elements the pickup values of which are given by the **Current level** and **Voltage level** settings respectively. Said elements activate at 95% of the pickup setting and reset at 100% of said setting.

The Dead Line detector can be applied only when the voltage transformer is on the line side and has been designed to activate with no need for digital inputs. The deactivation of **Any Dead Phase** signal indicates breaker status change (from open to closed).

The Dead Line Detector blocks when the **Fuse Fail Block** signal (**BLK_FF**) activates, given the lack of reliability of undervoltage detectors on fuse failure conditions. Figure 3.7.1 Logic diagram of the Dead Line Detector, shows the operation of this element.

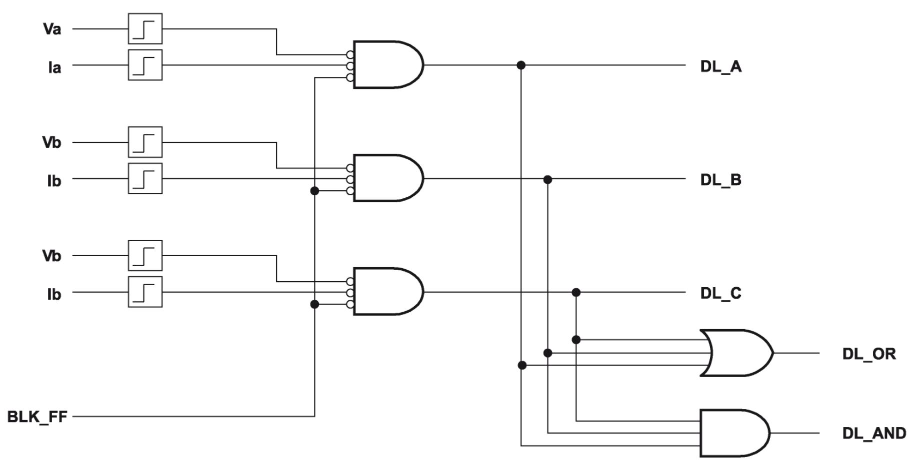

Figure 3.7.1 Logic Diagram of the Dead Line Detector.

3.7.2 Dead Line Detector Settings

Dead Line Detector			
Setting	**Range**	**Step**	**By default**
Dead Line Detector Enable	YES / NO		NO
Dead Line Current Level	0.2 - 4 A	0.01 A	0,2 A
Dead Line Voltage Level	2 - 70 V	0.01 V	45 V

- **Dead Line Detector: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	**2 - DEAD LINE DETECTOR**
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	4 - OVERCURRENT
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - GENERAL	0 - LINE DIFFERENTIAL	**0 - DL DETEC ENABLE**
1 - PROTECTION	1 - FUSE FAILURE	**1 - CURRENT LEVEL**
2 - RECLOSER	**2 - DEAD LINE DETECTOR**	**2 - VOLTAGE LEVEL**
3 - LOGIC	3 - OPEN POLE LOGIC	
...	...	

3.7.3 Digital Inputs and Events of the Dead Line Detector

Table 3.7-1: Digital Inputs and Events of the Dead Line Detector

Name	Description	Function
ENBL_DL	Dead Line Detector Enable Input	Its activation sets the element into operation. It can be assigned to a level digital input or communications protocol or MMI command. Default value of this logic input is “1”.

3.7.4 Digital Outputs and Events of the Dead Line Detector

Table 3.7-2: Digital Outputs and Events of the Dead Line Detector

Name	Description	Function
DL_A	Dead Phase A	Indication of phase A deenergized.
DL_B	Dead Phase B	Indication of phase B deenergized.
DL_C	Dead Phase C	Indication of phase C deenergized.
DL_OR	Any Dead Phase	Indication of any phase deenergized
DL_AND	Three Dead Phases	Indications of three-phases deenergized
DL_ENBLD	Dead Line Detector Enabled	Indication of element enabled or disabled state.
ENBL_DL	Dead Line Detector Enable Input	The same as for the digital input.

3.8 Overcurrent Elements

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3.8.9	Overcurrent Elements Test	3.8-41

Overcurrent Protection Elements
Three Phase Instantaneous Overcurrent Elements (50F1, 50F2 and 50F3)
Three Ground Instantaneous Overcurrent Elements (50N1, 50N2 and 50N3)
Three Negative Sequence Instantaneous Overcurrent Elements (50Q1, 50Q2 and 50Q3)
One Sensitive Ground Instantaneous Overcurrent Element (50NS)
Three Phase Time Overcurrent Elements (51F1, 51F2 and 51F3)
Three Ground Time Overcurrent Elements (51N1, 51N2 and 51N3)
Three Negative Sequence Time Overcurrent Elements (51Q1, 51Q2 and 51Q3)
One Sensitive Ground Time Overcurrent Element (51NS)

3.8.1 Phase, Ground, Sensitive Ground and Negative Sequence Instantaneous Elements

The Phase, Ground, Sensitive Ground and Negative Sequence Instantaneous Overcurrent Elements work according to the RMS value of the input currents. They operate when the RMS value exceeds a value 1.05 times the pickup setting and reset at 1 times the set value.

Each of these elements has an adjustable timer at the output that allows the optional delay of the instantaneous elements.

3.8.2 Phase, Ground, Sensitive Ground and Negative Sequence Time Elements

In the phase, Ground, Sensitive Ground and Negative Sequence Time Overcurrent Elements, the overcurrent Time Delay function operates on the RMS of the input current. Pickup occurs when the value measured exceeds 1.05 times the pickup setting and resets at the pickup setting.

The pickup activates the timer, which integrates the measured values. The algorithm increases a counter depending on the input current. The counter limit determines the timer element activation.

When the RMS falls below the pickup setting, a rapid reset of the integrator occurs. The activation of the output requires that the pickup continue throughout the integration time; any reset returns the integrator to its initial conditions so that a new operation initiates the time count from zero.

The time curve can be selected from among several types of curves according to **IEC**, **IEEE** (IEEE Standard C37.112-1996) and **US** standards:

IEC CURVES

Inverse Curve	Inverse Curve + Time Limit
Very Inverse Curve	Very Inverse Curve + Time Limit
Extremely Inverse Curve	Extremely Inverse Curve + Time Limit
Long-Term Inverse Curve	Long-Term Inverse Curve + Time Limit
Short-Term Inverse Curve	Short-Term Inverse Curve + Time Limit

IEEE CURVES

Moderately Inverse Curve	Moderately Inverse Curve + Time Limit
Very Inverse Curve	Very Inverse Curve + Time Limit
Extremely Inverse Curve	Extremely Inverse Curve + Time Limit

US CURVES

Moderately Inverse Curve	Moderately Inverse Curve + Time Limit
Inverse Curve	Inverse Curve + Time Limit
Very Inverse Curve	Very Inverse Curve + Time Limit
Extremely Inverse Curve	Extremely Inverse Curve + Time Limit
Short-Term Inverse Curve	Short-Term Inverse Curve + Time Limit

In addition to these curves, there is the **RI Inverse** curve, used primarily to coordinate with electromechanical relays.

The curve index setting is the same for the **IEC** curves, the **IEEE** curves, the **US** curves and the **RI Inverse** curve: their range is from 0.05 to 10 times the set current.

However, the effective range for the **IEC** curves is from 0.05 to 1. Settings above 1 use the maximum value, which is 1. In the case of the other curves (**IEEE**, **US** and **RI**), the effective range starts at 0.1 times the setting. Lower settings act as if they were set to the minimum (0.1 times the setting). Moreover, although the setting step is 0.01, the effective step for these three types of curve is 0.1. Any setting that is not a multiple of 0.1 is rounded off; that is, a setting of 2.37 is applied as if it were 2.40 and a setting of 2.33 is applied as if it were 2.30 (the setting 2.35 is applied as if it were 2.40).

You can add a **User-Defined** time curve to these and load it on the relay via the communications system. The time setting, in the inverse time curves, is composed of two values: **Curve Type** and **Index** within the family.

Time Limit curves have a classical delay function with a time threshold, so that no trip will occur sooner than specified. This amounts to changing the trip curve into a horizontal straight line at a given moment. This limit on the operation of the element coincides with the time setting in the **Fixed Time** option.

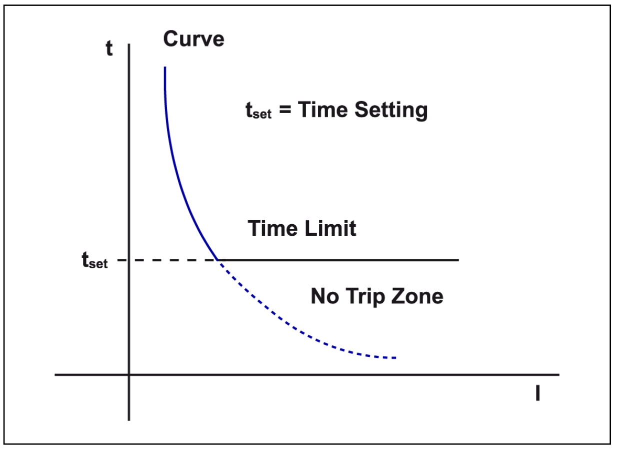

Figure 3.8.1 Diagram of a Curve with a Time Limit for a Time Overcurrent Element.

The **Fixed Time** setting ranges may be excessive for the times of the curve. If the time of the curve (for the dial set and for a current 1.5 times greater than the set current) is less than the **Fixed Time** setting, the operation of the element uses 1.5 times the set current as the straight line limit.

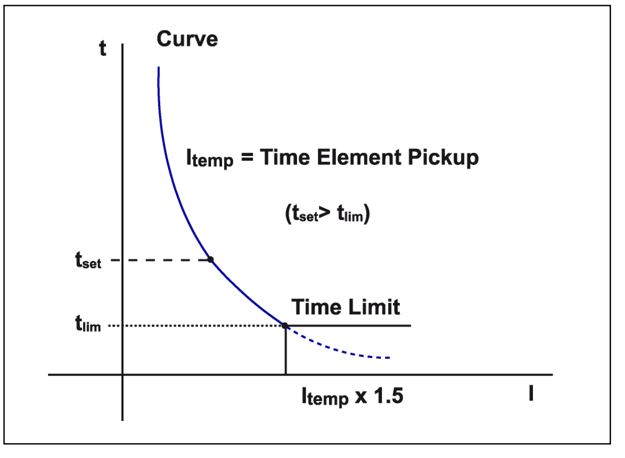

Figure 3.8.2 Time Limit of the Element when the Fixed Time is Greater than the Curve Time (in pickup x 1.5).

Note: although the curves are defined for an input value of up to 20 times the tap, which is the set pickup value in each of the time overcurrent elements, this range cannot always be guaranteed. It is important to consider that the saturation limit of the current channels is 160A. Based on these limits, the "number of times the tap" for which the curves are effective depends on the setting:

a. If $\frac{SaturationLimit}{ElementSetting} > 20$**, the curve is guaranteed to work for the element with this setting throughout its range of taps (up to 20 times the setting).**

b. If $\frac{SaturationLimit}{ElementSetting} < 20$**, the curve is guaranteed to work for the element with this setting up to a number of times the tap equal to the value of this limit divided by the corresponding setting.**

When a current greater than 20 times the setting is injected, the trip time will be the same as that corresponding to these 20 times.

3.8.2.a Current / Time Curve: Inverse Functions

Figures 3.8.3, 3.8.4, 3.8.5, 3.8.6 and 3.8.7 present the inverse curves according to the **IEC** standards.

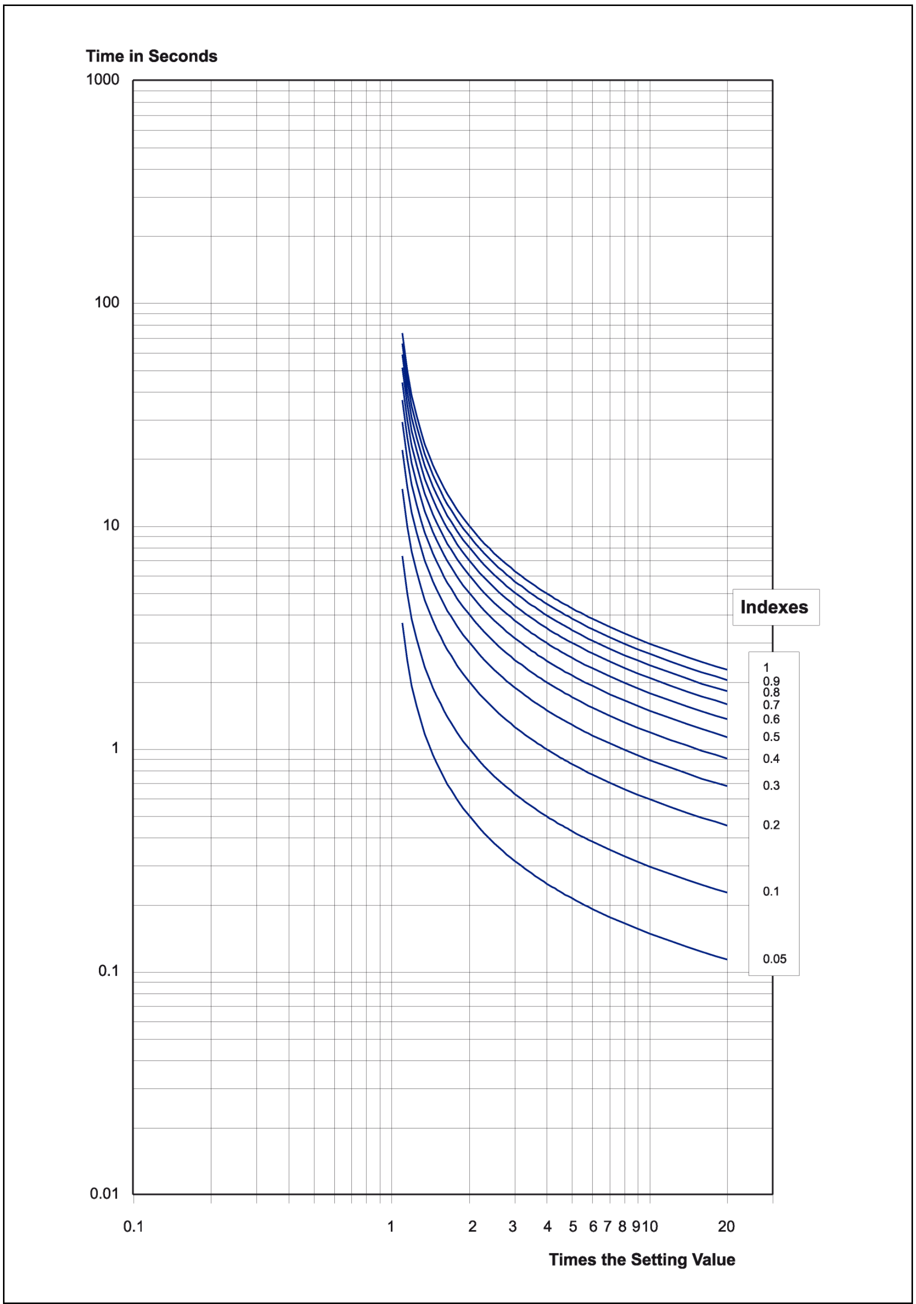

Figure 3.8.3 INVERSE Time Curve (IEC).

$t = \dfrac{0.14}{I_S^{0.02} - 1} \times \text{Index}$	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

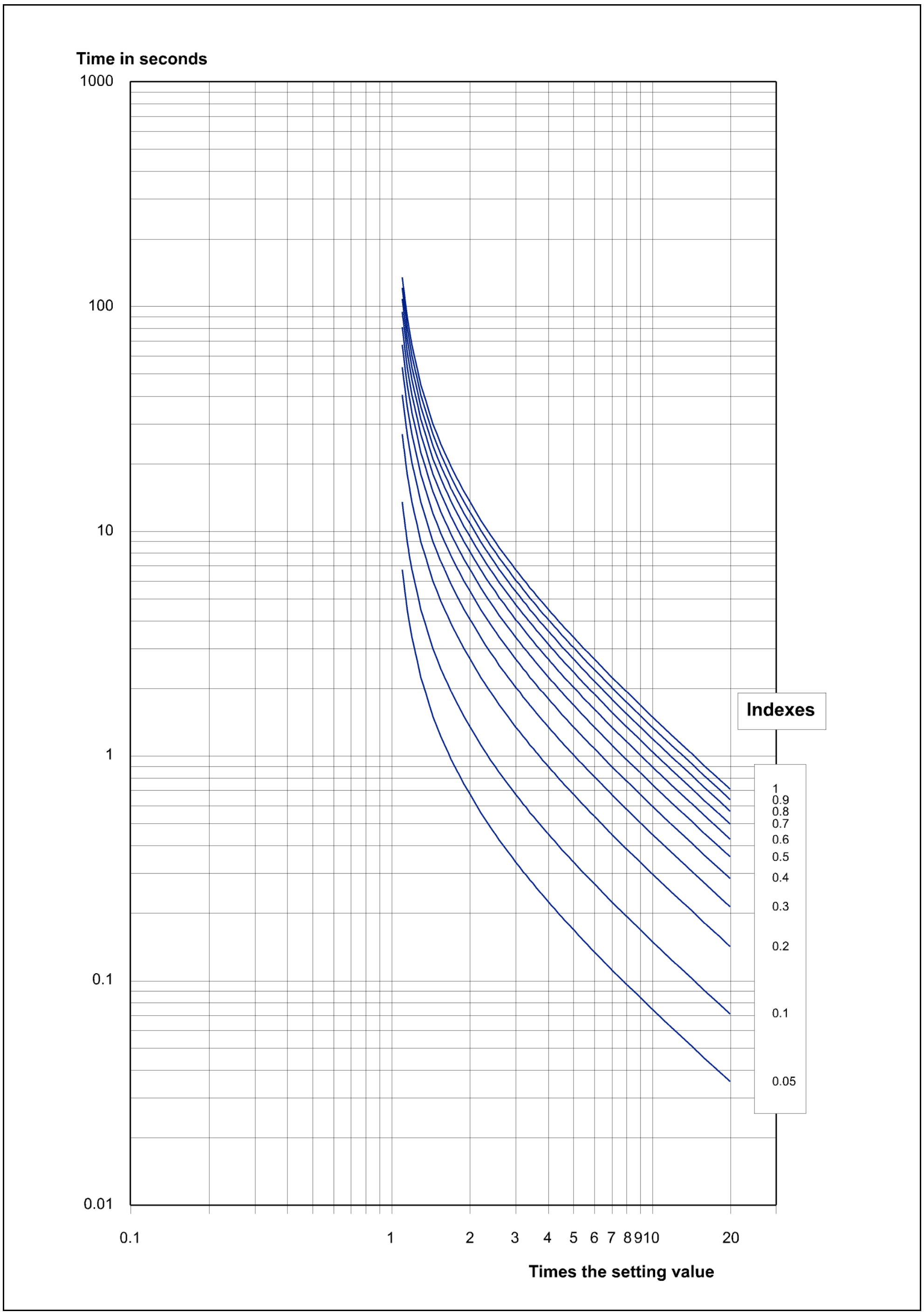

Figure 3.8.4 VERY INVERSE Time Curve (IEC).

$t = \dfrac{13.5}{I_S - 1}$ x Index	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

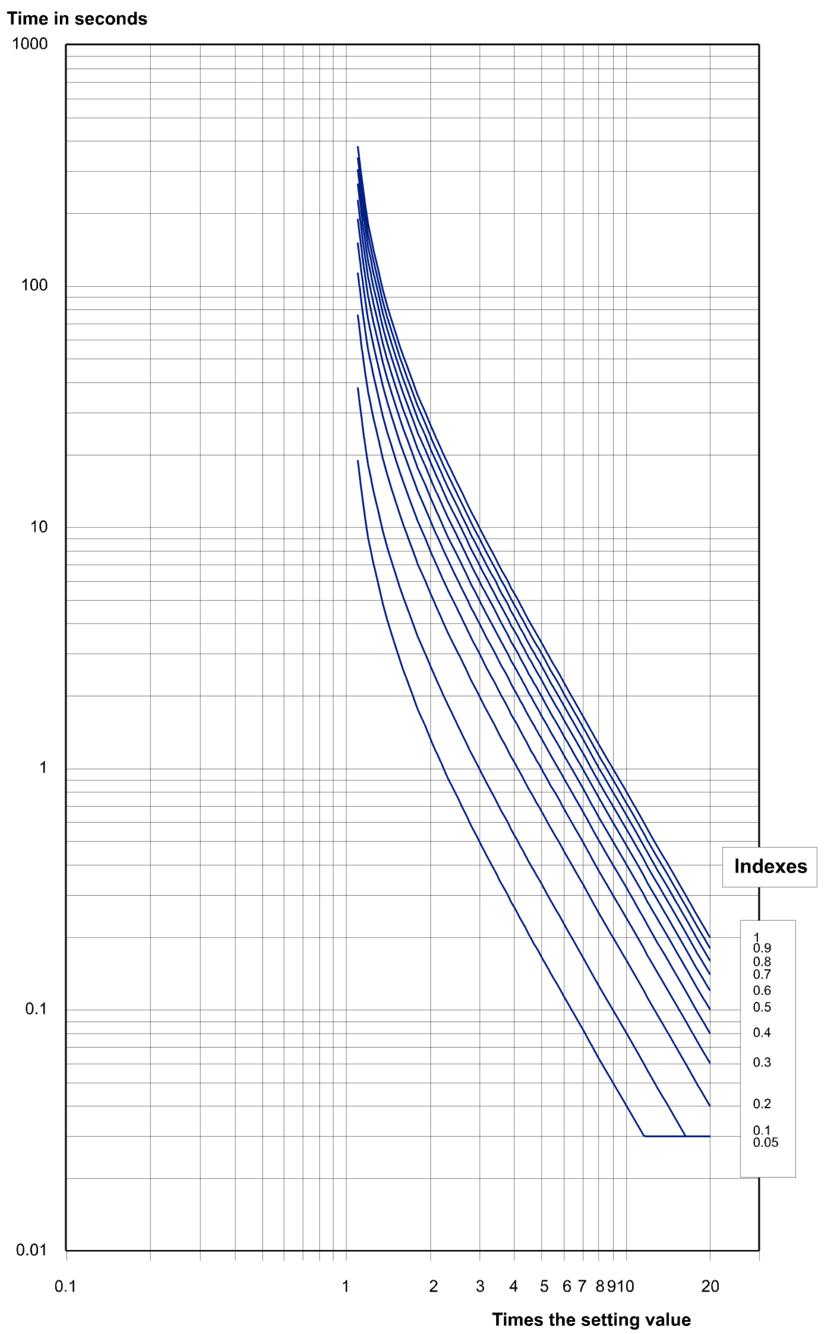

Figure 3.8.5 EXTREMELY INVERSE Time Curve (IEC).

$t = \dfrac{80}{I_S^{\,2} - 1}$ x Index	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

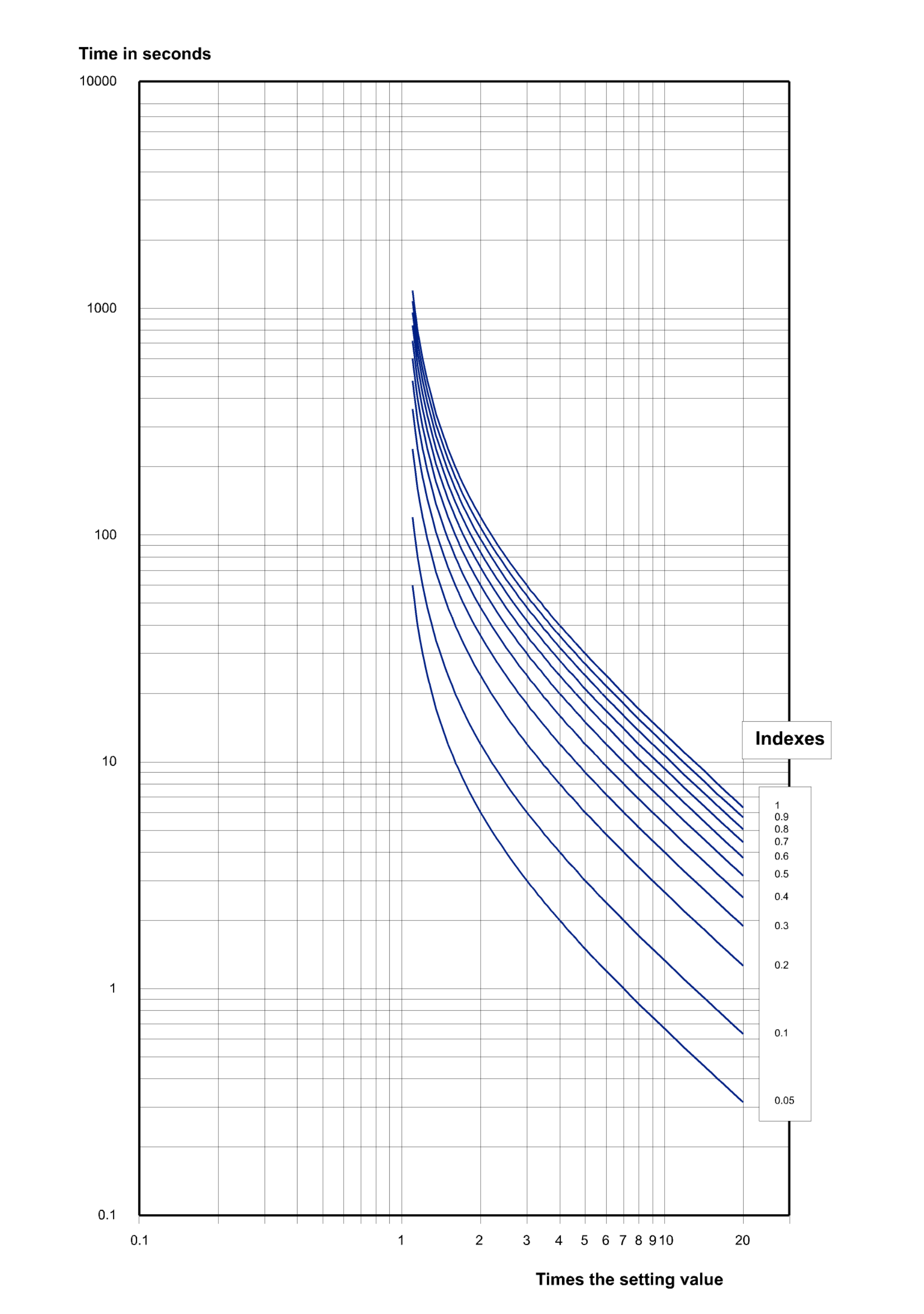

Figure 3.8.6 LONG TIME-INVERSE Curve (IEC).

$t = \frac{120}{I_S - 1}$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

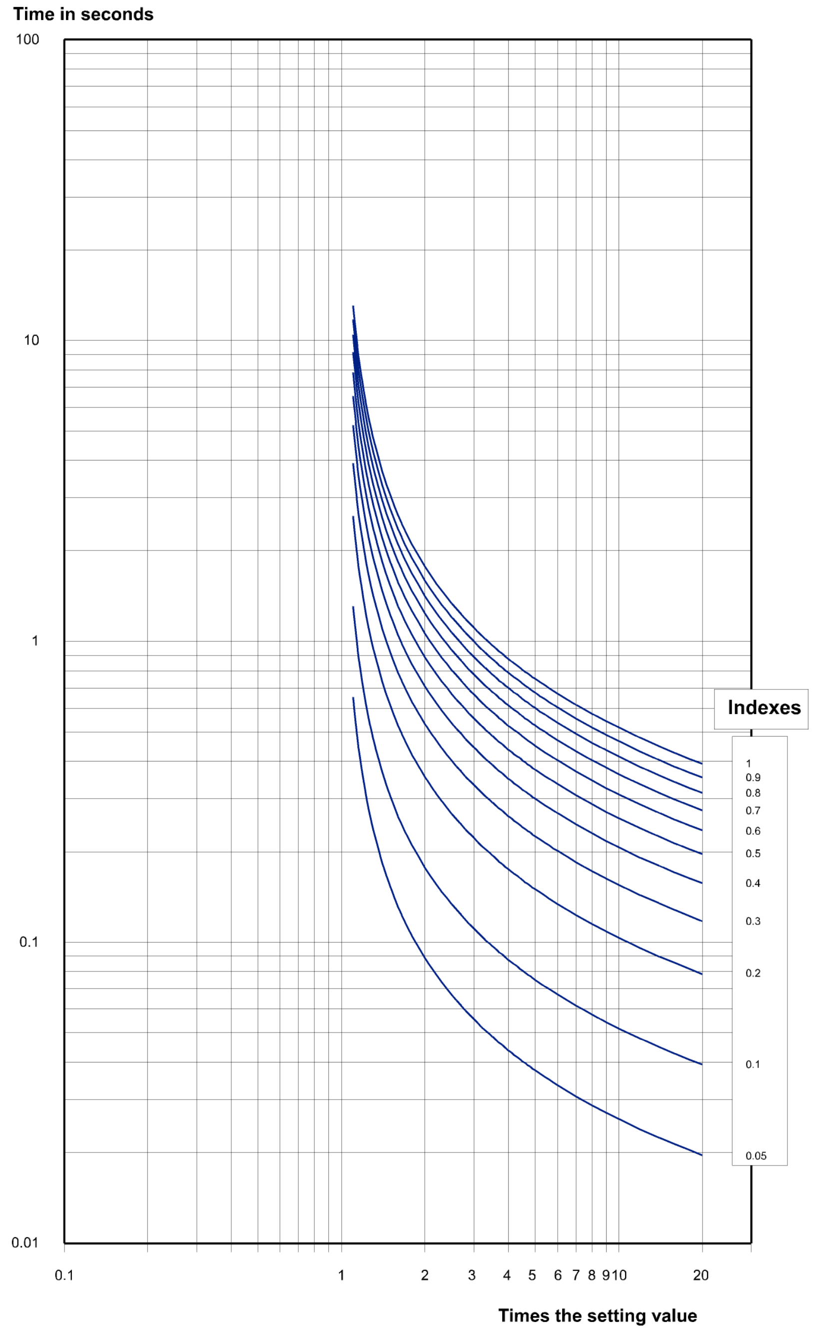

Figure 3.8.7 SHORT TIME-INVERSE Curve (IEC).

$t = \dfrac{0.05}{I_S^{\;0.04} - 1}$ x Index	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

Figures 3.8.8, 3.8.9, 3.8.10, 3.8.11, 3.8.12, 3.8.13, 3.8.14 and 3.8.15 present the inverse curves according to the **IEEE** and **US** standards.

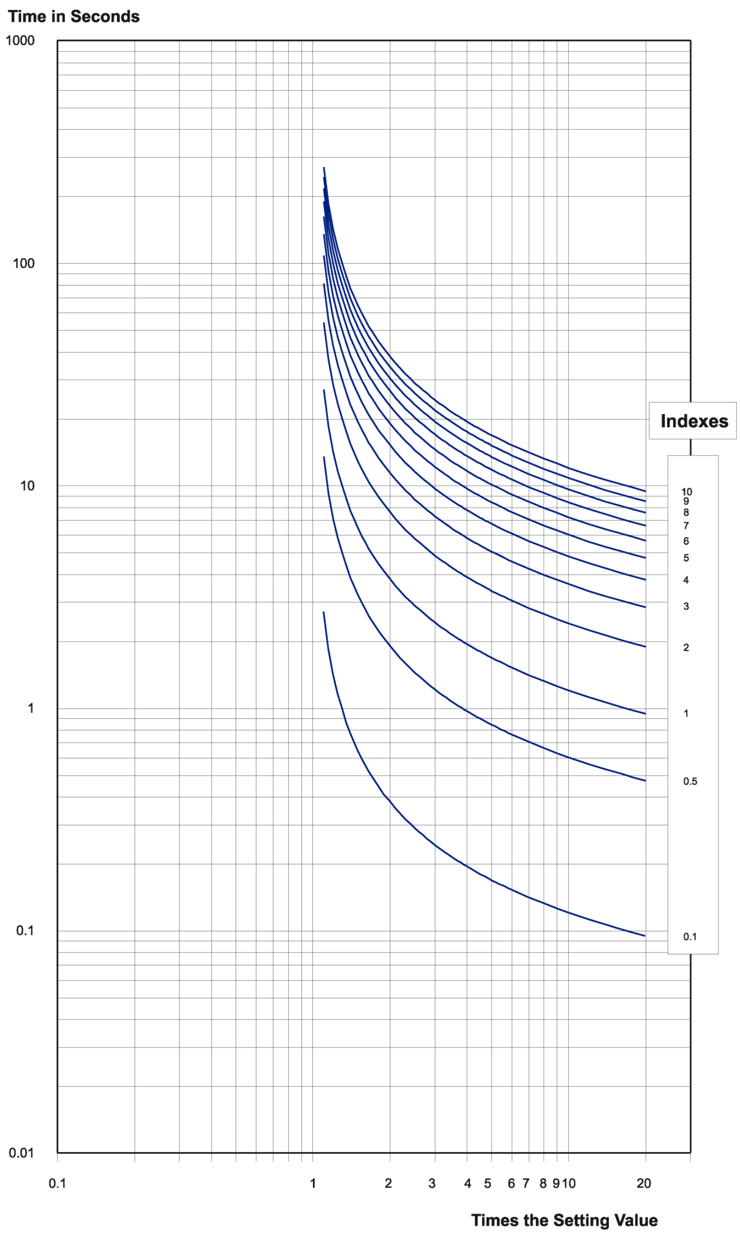

Figure 3.8.8 MODERATELY INVERSE Time Curve (IEEE).

$t = \left(0.114 + \frac{0.0515}{I_S^{0.02} - 1}\right)$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

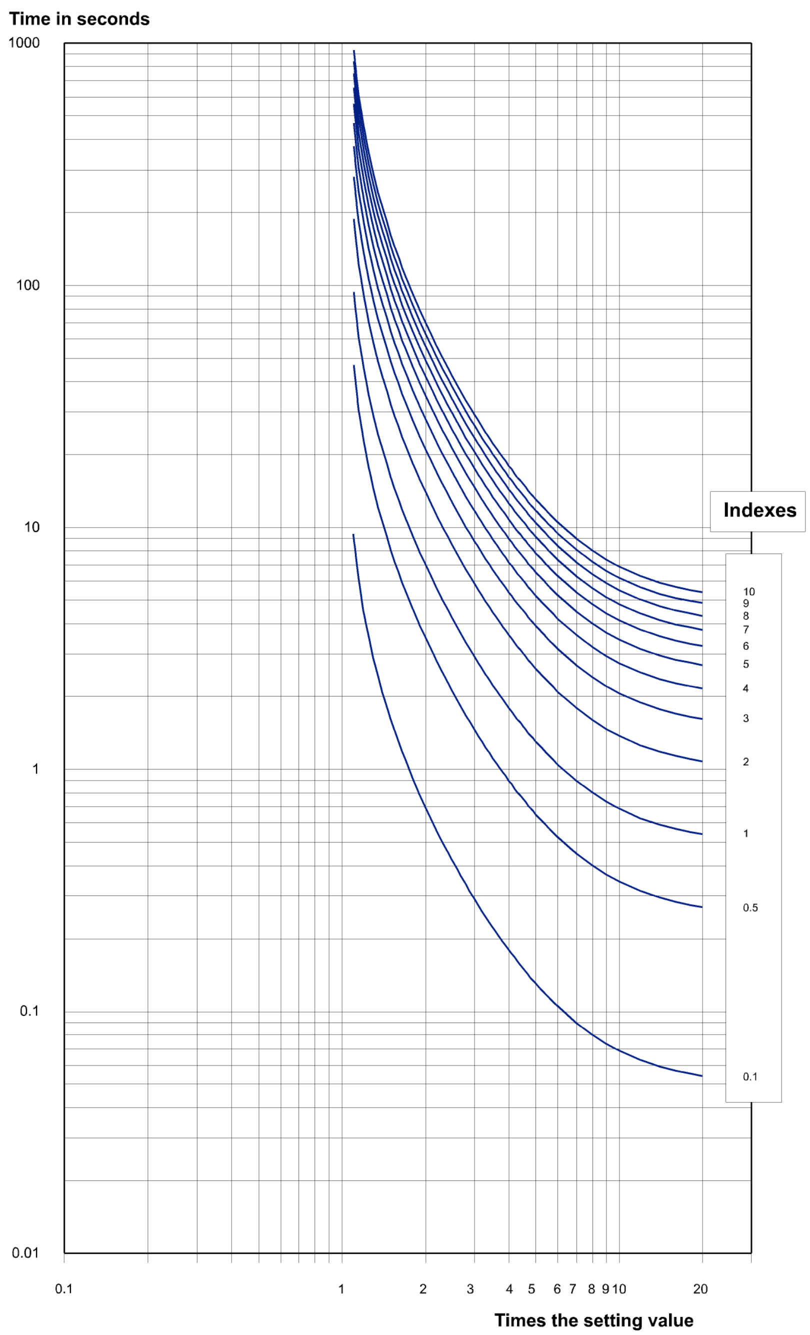

Figure 3.8.9 VERY INVERSE Time Curve (IEEE).

$t = \left(0.491 + \dfrac{19.61}{I_S^{\,2} - 1}\right)$ x Index	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

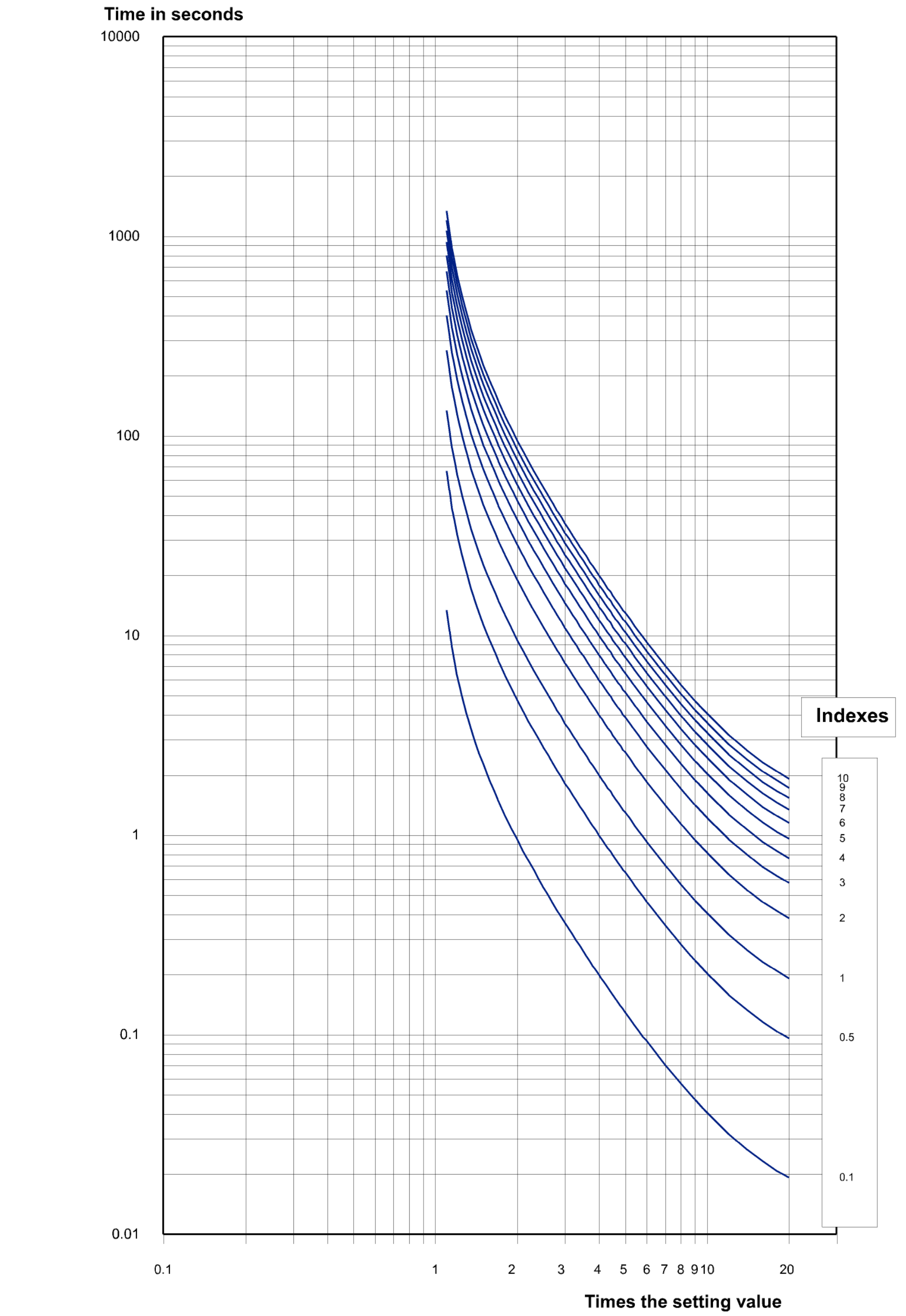

Figure 3.8.10 EXTREMELY INVERSE Time Curve (IEEE).

$t = \left(0.1217 + \dfrac{28.2}{I_S^{\,2} - 1} \right)$ x Index	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

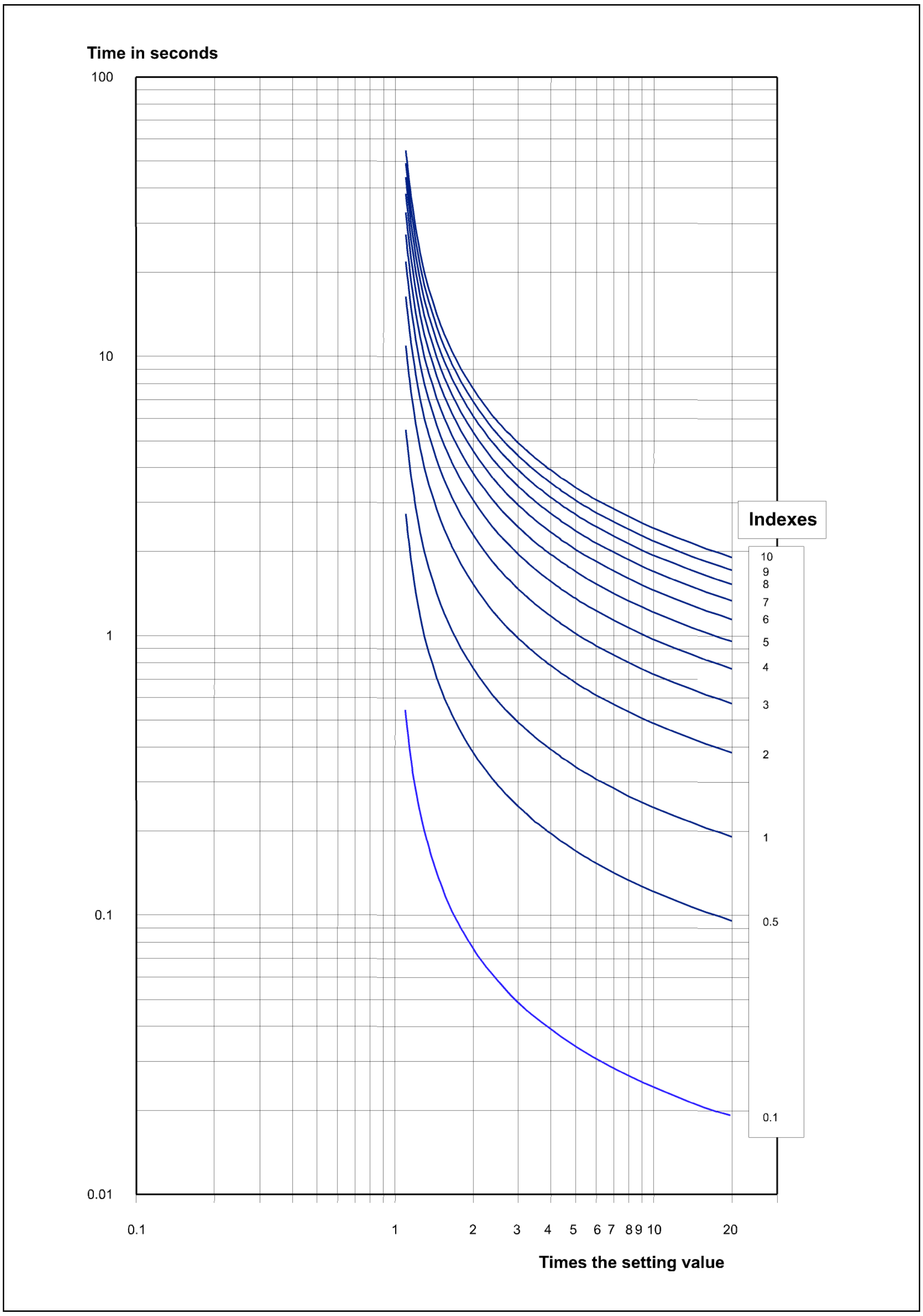

Figure 3.8.11 MODERATELY INVERSE Time Curve (U.S.)

$t = \left(0.0226 + \frac{0.0104}{I_S^{0.02} - 1} \right)$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

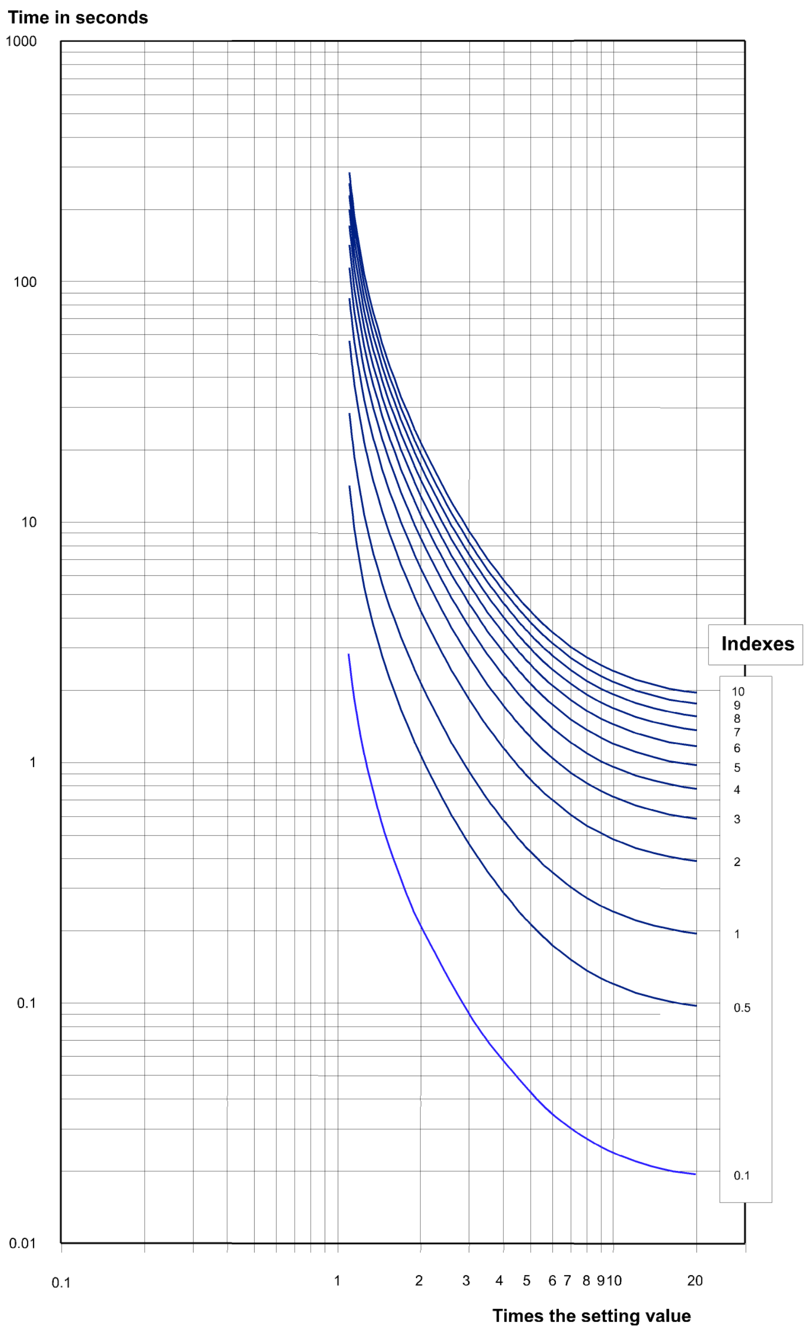

Figure 3.8.12 INVERSE Time Curve (U.S.).

$t = \left(0.180 + \dfrac{5.95}{I_S^{\,2} - 1}\right)$ x Index	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

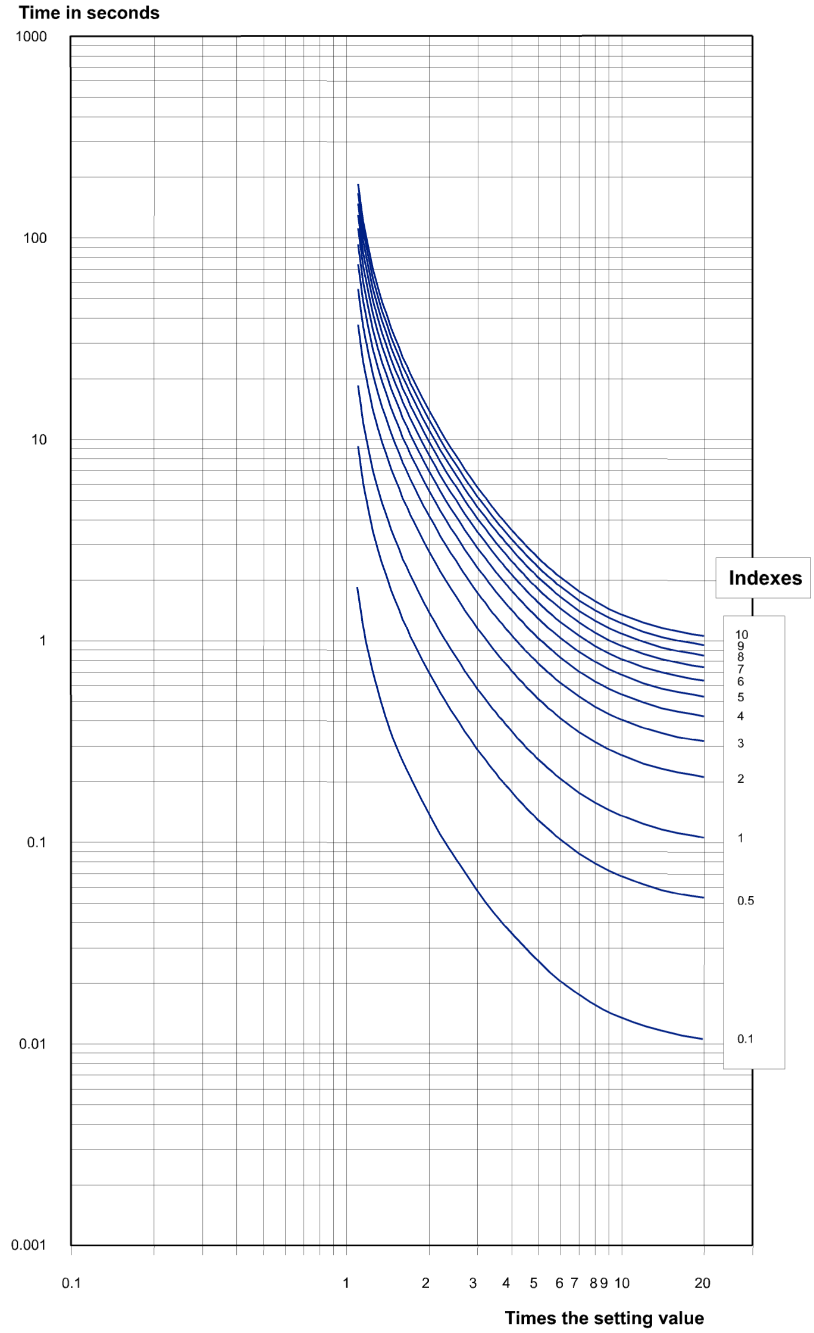

Figure 3.8.13 VERY INVERSE Time Curve (U.S.).

$t = \left(0.0963 + \dfrac{3.88}{I_S^{\,2} - 1} \right)$ x Index	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

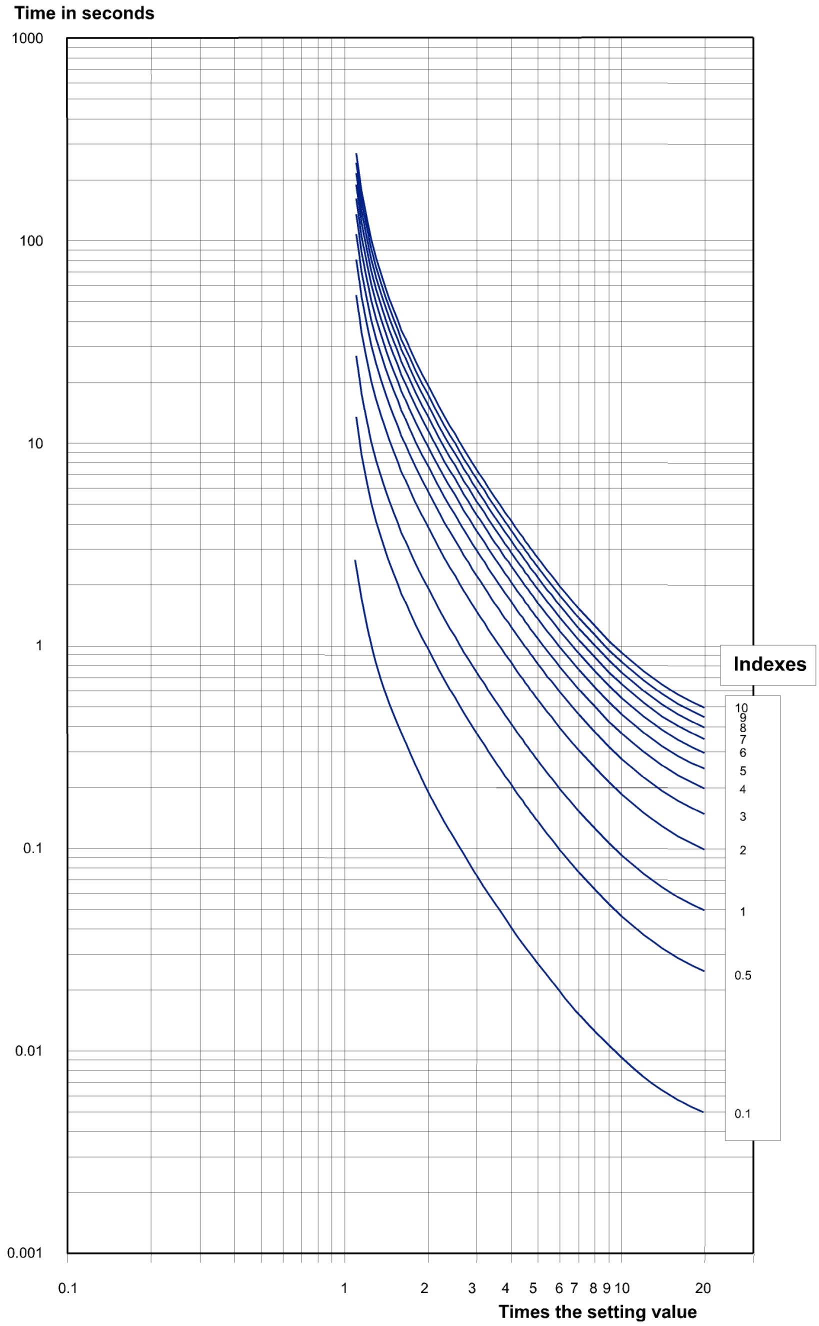

Figure 3.8.14 EXTREMELY INVERSE Time Curve (U.S.).

$t = \left(0.0352 + \dfrac{5.67}{I_S^{\,2} - 1} \right)$ x Index	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

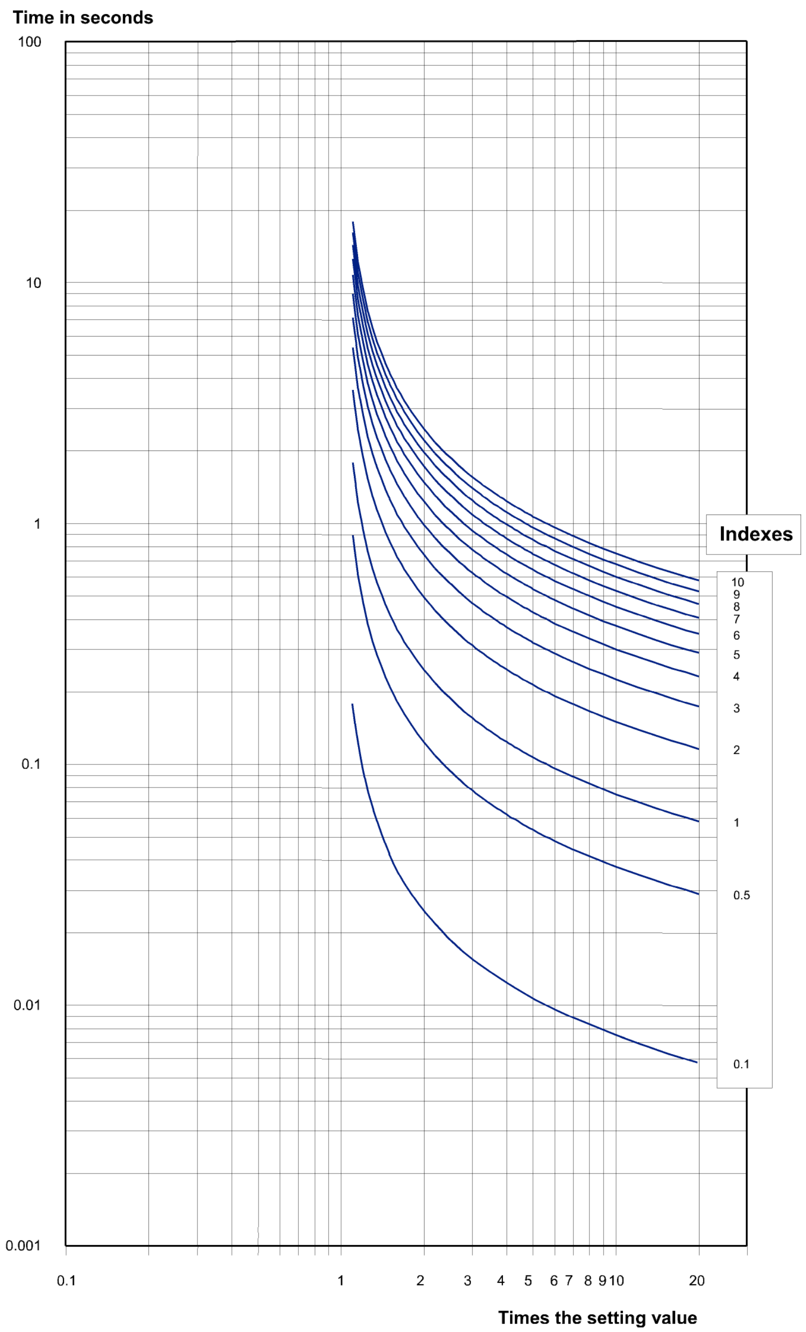

Figure 3.8.15 SHORT INVERSE Time Curve (U.S.).

$t = \left(0.00262 + \dfrac{0.00342}{I_S^{0.02} - 1}\right)$ x Index	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

And figure 3.8.16 presents the **RI Inverse** curve available for the **DLX** models.

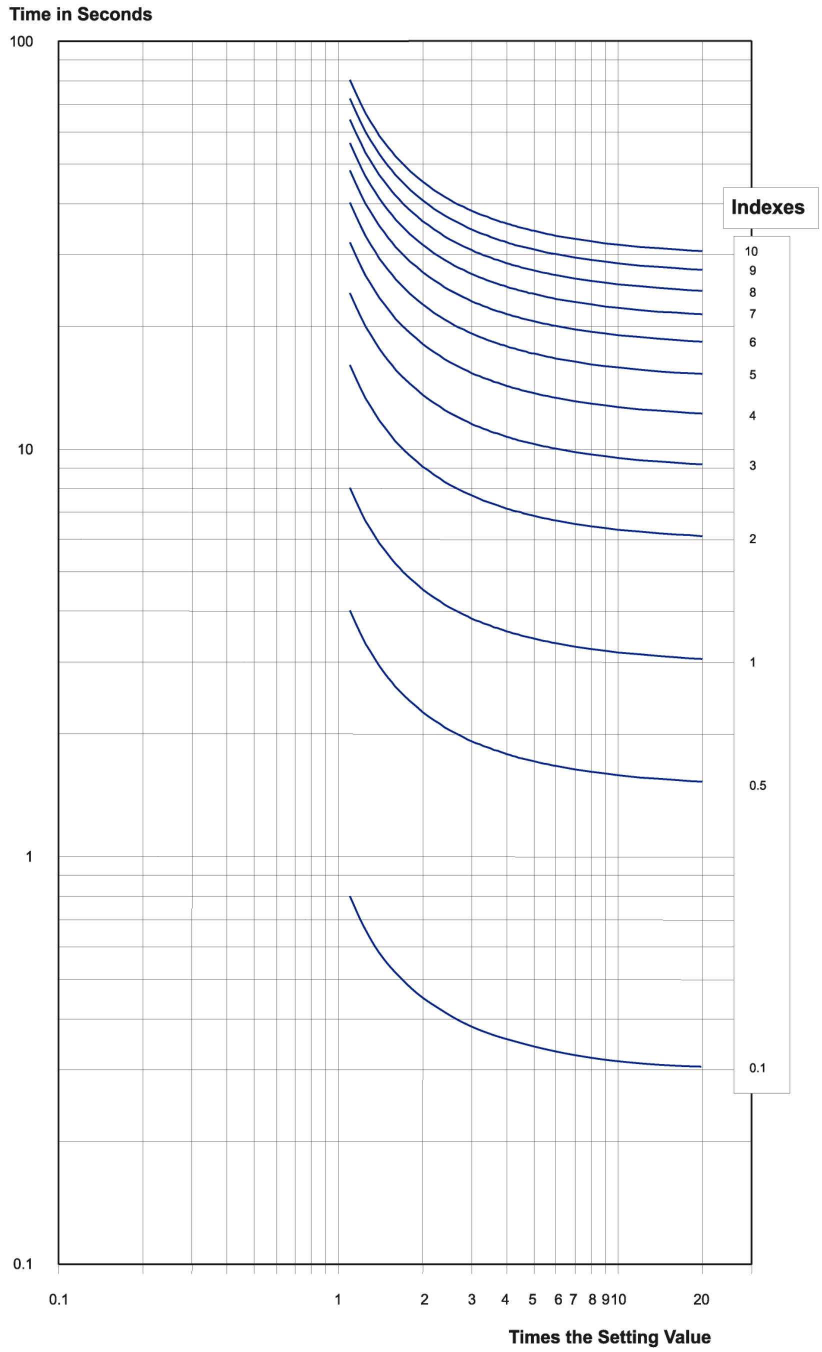

Figure 3.8.16 RI INVERSE Time Curve.

$t = \dfrac{1}{0.339 - 0.236 \cdot \left(\dfrac{1}{I_S}\right)}$ x Index	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

3.8.3 Torque Control

The **Torque Control** setting associated with an overcurrent unit allows selecting the directionality of this unit. Possible setting values are:

0 - There is no permission to use directionality.
1 - Permission to use the indications in the co-direction current.
2 - Permission to use the indications in the reverse current.

An element with **Torque Control** set to zero becomes non-directional.

On the other hand, the **Torque Control Type** setting corresponding to an overcurrent unit allows selecting the type of directional unit in charge of subordinating it. The possible values that this setting can take for the different types of overcurrent units are indicated in the following.

Ground Overcurrent (Instantaneous or Time Elements):

67N (Ground Directional Element).
67Q (Negative Sequence Directional Element).

The 67Q option may be interesting vs. the 67N option when very low V0 voltage levels are anticipated, less than the minimum threshold to polarize the ground directional unit. This condition may arise in very strong zero-sequence source systems (low impedance of zero-sequence local source). On the other hand, the 67Q option may be of interest when there are large mutual couplings (zero sequence) with a parallel line, which could distort the V0 voltage.

3.8.4 Block Trip and Bypass Time

Both instantaneous and time overcurrent elements can program **Block Trip** inputs, which prevents the operation of the element if this input is activated before the trip is generated. If activated after the trip, it resets. To be able to use these logic input signals, it is necessary to program the status contact inputs defined as block trip.

Another programmable input can change a time overcurrent element into an instantaneous element. This input is called **Bypass Time** and is available for all the time overcurrent elements.

3.8.5 Operation of the Overcurrent Elements

3.8.5.a Instantaneous Elements

Operation of the Instantaneous Elements is shown in the block diagrams of Figures 3.8.17, 3.8.18, 3.8.19 and 3.8.20.

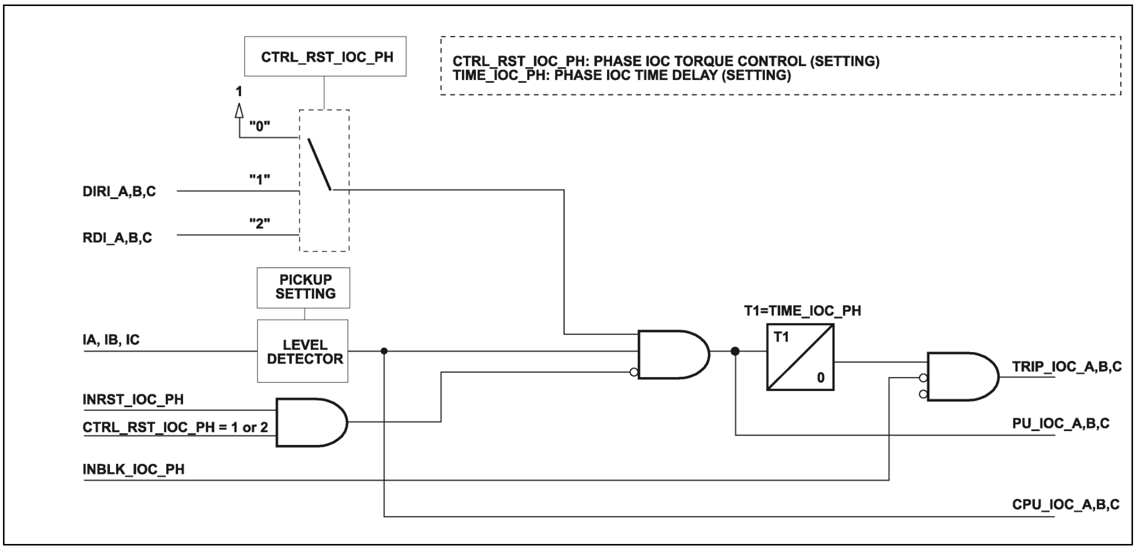

Figure 3.8.17 Block Diagram of a Phase Instantaneous Overcurrent Element.

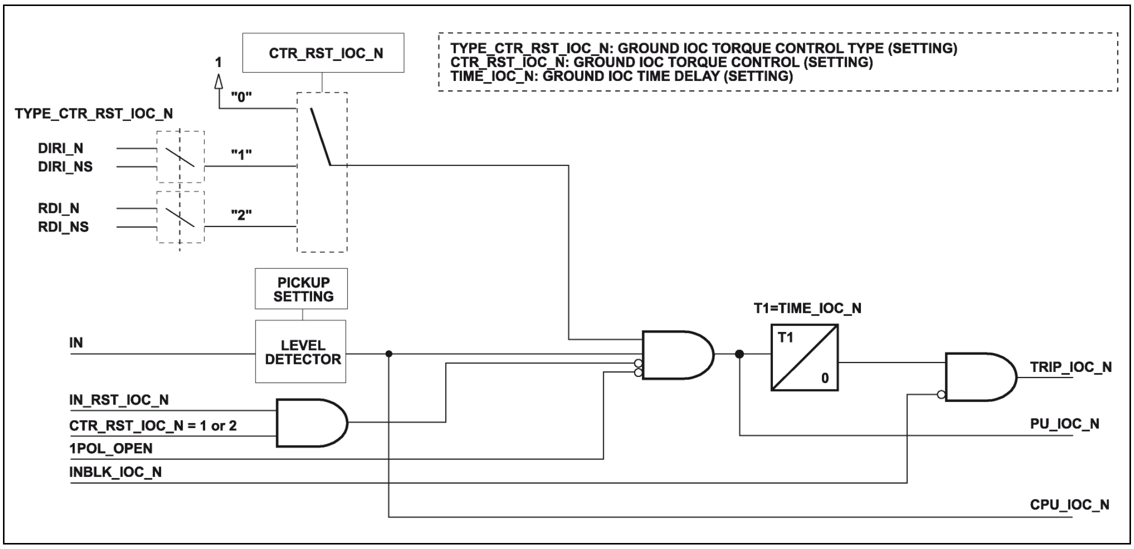

Figure 3.8.18 Block Diagram of a Ground Instantaneous Overcurrent Element.

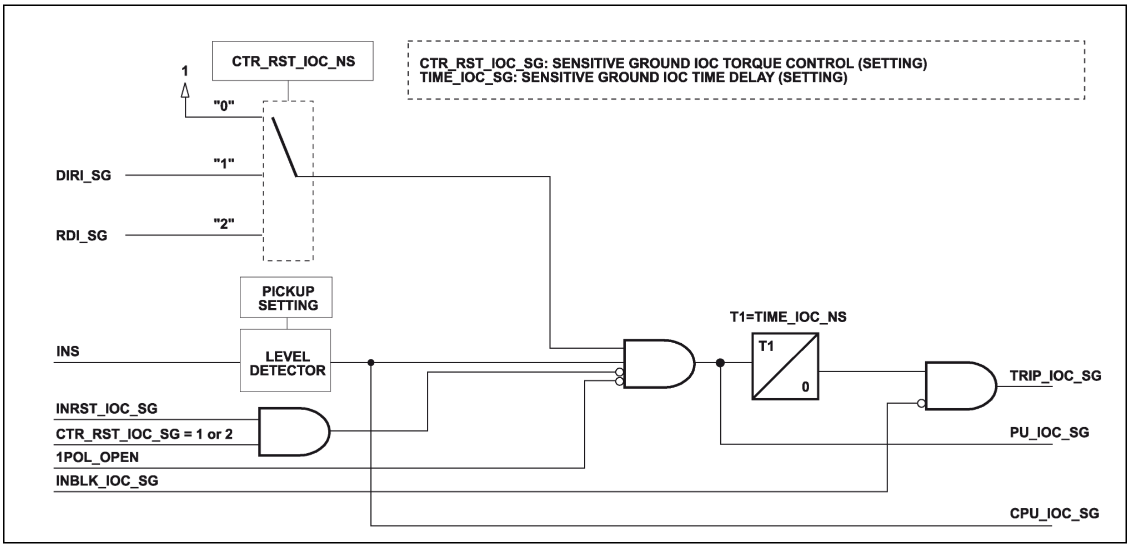

Figure 3.8.19 Block Diagram of a Sensitive Ground Instantaneous Overcurrent Element.

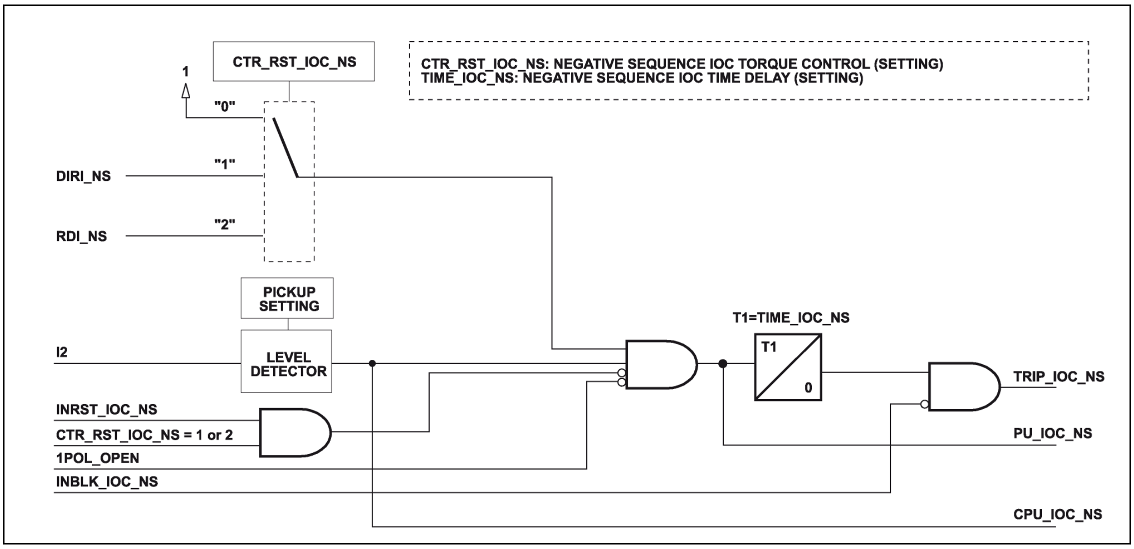

Figure 3.8.20 Block Diagram of a Negative Sequence Instantaneous Overcurrent Element.

Figures 3.8.18, 3.8.19 and 3.8.20 show the blocking that the **One Open Pole** (**1POL_OPEN**) signal carries out on the ground, sensitive ground and negative sequence overcurrent units, in order to prevent its pickup in case of a new situation originated by the aperture of a pole.

The **Torque Disable** input associated with each instantaneous overcurrent unit (**INRST_IOC**) blocks the pickup of the unit, provided that this includes directionality (torque control = 1 or 2).

The **Directional** (**DIRI**) and **Reverse Direction** (**RDI**) signals included in the previous diagrams originate from the directional units described in 3.9.

3.8.5.b Time-Delayed Elements

Operation of the time delayed elements is also shown in the block diagrams of Figures 3.8.21, 3.8.22, 3.8.23 and 3.8.24.

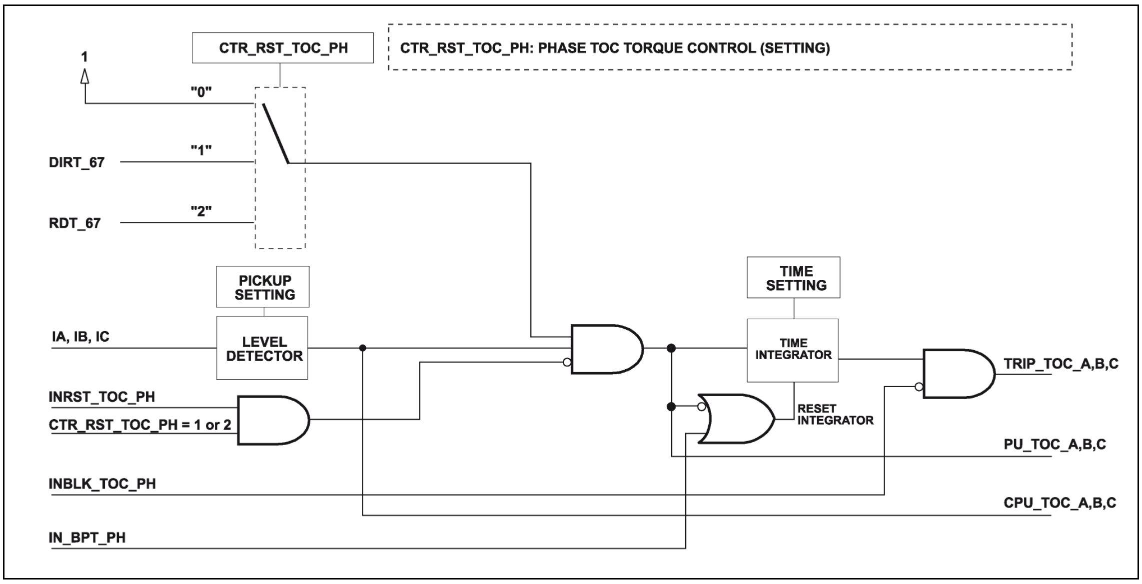

Figure 3.8.21 Block Diagram of a Phase Time Overcurrent Element.

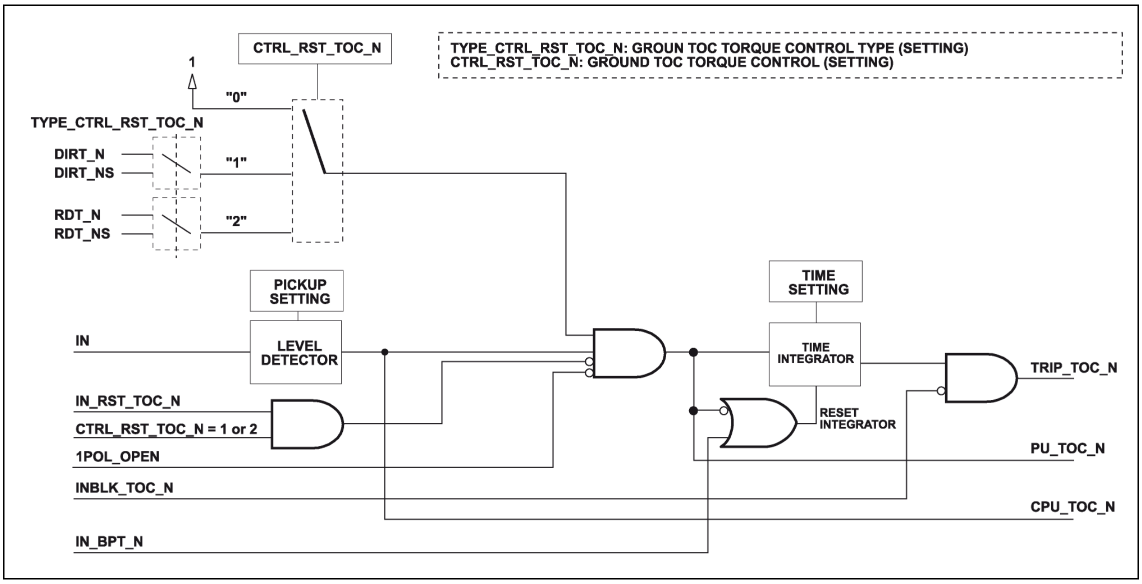

Figure 3.8.22 Block Diagram of a Ground Time Overcurrent Element.

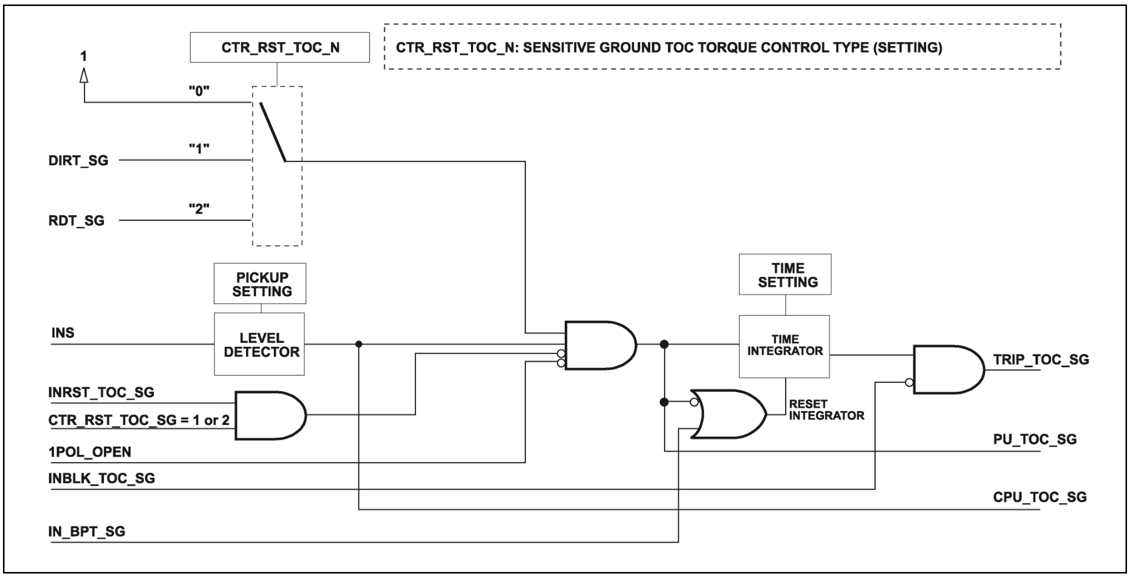

Figure 3.8.23 Block Diagram of a Sensitive Ground Time Overcurrent Element.

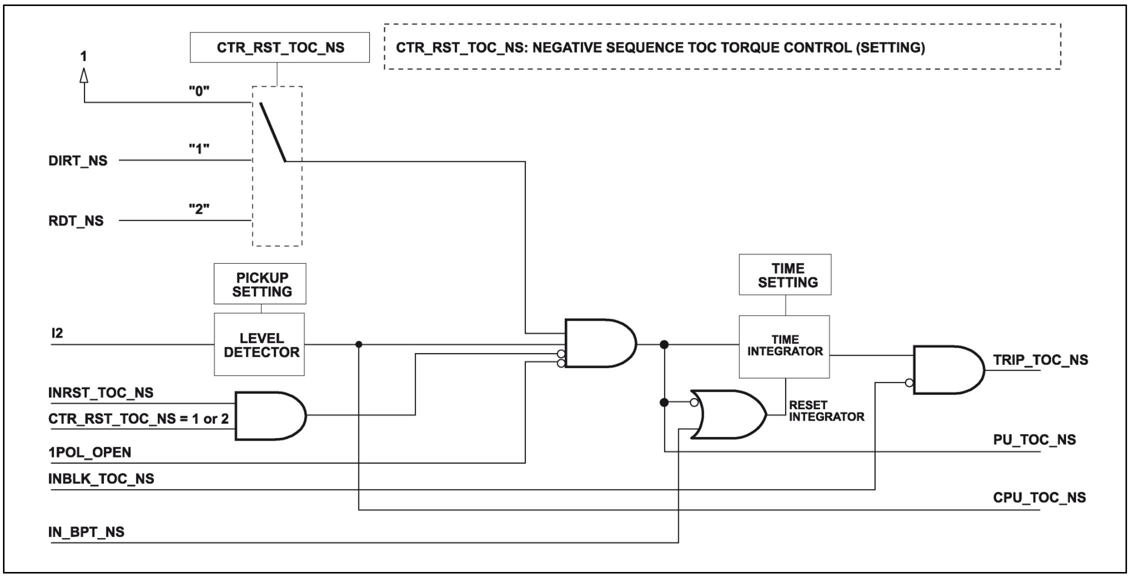

Figure 3.8.24 Block Diagram of a Negative Sequence Time Overcurrent Element.

Figures 3.8.22, 3.8.23 and 3.8.24 show the blocking that the **Open Pole** (**1POL_OPEN**) signal carries out on Ground, Sensitive Ground and Negative Sequence Overcurrent units, in order to prevent its pickup in case of a new situation arising as a result of the aperture of a pole.

The **Torque Disable** input associated with each time overcurrent unit (**INRST_TOC**) blocks the pickup of the unit provided that this includes directionality (torque control =1 or 2).

The **Directional** (**DIRT**) and **Reverse Direction** (**RDT**) signals included in the previous diagrams originate from the directional units, described in 3.9.

3.8.6 Overcurrent Elements Settings

Phase Instantaneous Overcurrent (Elements 1, 2 and 3)			
Setting	**Range**	**Step**	**By default**
Enable	YES / NO		NO
Pickup	(0.01 - 30) In	0.01 A	In
Time Delay	0 - 300 s	0.01 s	0 s
Torque Control (Pickup Blocking Enable)	0: Non-directional 1: Directional 2: Reverse direction		0: Non-directional

Ground Instantaneous Overcurrent (Elements 1, 2 and 3)			
Setting	**Range**	**Step**	**By default**
Enable	YES / NO		NO
Pickup	(0.12 - 30) In	0.01 A	In
Time Delay	0 - 300 s	0.01 s	0 s
Torque Control (Pickup Blocking Enable)	0: Non-directional 1: Directional 2: Reverse direction		0: Non-directional
Torque Control Type	0: Ground Directional Element (67N) 1: Negative Seq. Direct. Element (67Q)		0: Ground Dir. element

Sensitive Ground Instantaneous Overcurrent Element			
Setting	**Range**	**Step**	**By default**
Enable	YES / NO		NO
Pickup	0.005 – 3.00 A	0.001 A	0.1 A
Time Delay	0 - 600 s	0.01 s	0 s
Torque Control (Pickup Blocking Enable)	0: Non-directional 1: Directional 2: Reverse direction		0: Non-directional

Negative Sequence Instantaneous Overcurrent (Elements 1, 2 and 3)			
Setting	**Range**	**Step**	**By default**
Enable	YES / NO		NO
Pickup	(0.01 - 30) In	0.01 A	2 In
Time Delay	0 - 300 s	0.01 s	0 s
Torque Control (Pickup Blocking Enable)	0: Non-directional 1: Directional 2: Reverse direction		0: Non-directional

Phase Time Overcurrent (Elements 1, 2 and 3)			
Setting	**Range**	**Step**	**By default**
Enable	YES / NO		NO
Pickup	(0.02 - 25) In	0.01 A	0.4 In
Time Curve	See curve list		Fixed Time
Inverse Time Curve Dial	0.05 - 10	0.01	1
Effective Range for the IEC Curves	0.05 - 1	0.01	1
Effective Range for the IEEE/US Curves	0.1 - 10	0.01	1
Time Delay	0.05 - 300 s	0.01 s	0.05 s
Torque Control (Pickup Blocking Enable)	0: Non-directional 1: Directional 2: Reverse direction		0: Non-directional

Ground Time Overcurrent (Elements 1, 2 and 3)			
Setting	**Range**	**Step**	**By default**
Enable	YES / NO		NO
Pickup	(0.12 - 25) In	0.01 A	0.4 In
Time Curve	See curve list		Fixed Time
Inverse Time Curve Dial	0.05 - 10	0.01	1
Effective Range for the IEC Curves	0.05 - 1	0.01	1
Effective Range for the IEEE/US Curves	0.1 - 10	0.01	1
Time Delay	0.05 - 300 s	0.01 s	0.05 s
Torque Control (Pickup Blocking Enable)	0: Non-directional 1: Directional 2: Reverse direction		0: Non-directional
Torque Control Type	0: Ground Directional Element (67N) 1: Negative Seq. Dir. Element (67Q)		0: Ground dir. element

Sensitive Ground Time Overcurrent Element			
Setting	**Range**	**Step**	**By default**
Enable	YES / NO		NO
Pickup	0.005 - 2.0 A	0.001A	0.1 A
Time Curve	See curve list		Fixed Time
Inverse Time Curve Dial	0.05 - 10	0.01	1
Effective Range for the IEC Curves	0.05 - 1	0.01	1
Effective Range for the IEEE/US Curves	0.1 - 10	0.01	1
Time Delay	0.05 - 300 s	0.01 s	0.05 s
Torque Control (Pickup Blocking Enable)	0: Non-directional 1: Directional 2: Reverse direction		0: Non-directional

Negative Sequence Time Overcurrent (Elements 1, 2 and 3)			
Setting	**Range**	**Step**	**By default**
Enable	YES / NO		NO
Pickup	(0.1- 5.0) In	0.01 A	0.4 In
Time Curve	See curve list		Fixed Time
Inverse Time Curve Dial	0.05 - 10	0.01	1
Effective Range for the IEC Curves	0.05 - 1	0.01	1
Effective Range for the IEEE/US Curves	0.1 - 10	0.01	1
Time Delay	0.05 - 300 s	0.01 s	0.05 s
Torque Control (Pickup Blocking Enable)	0: Non-directional 1: Directional 2: Reverse direction		0: Non-directional

List of Available Curves

IEC CURVES

Inverse Curve	Inverse Curve + Time Limit
Very Inverse Curve	Very Inverse Curve + Time Limit
Extremely Inverse Curve	Extremely Inverse Curve + Time Limit
Long-Term Inverse Curve	Long-Term Inverse Curve + Time Limit
Short-Term Inverse Curve	Short-Term Inverse Curve + Time Limit

IEEE CURVES

Moderately Inverse Curve	Moderately Inverse Curve + Time Limit
Very Inverse Curve	Very Inverse Curve + Time Limit
Extremely Inverse Curve	Extremely Inverse Curve + Time Limit

US CURVES

Moderately Inverse Curve	Moderately Inverse Curve + Time Limit
Inverse Curve	Inverse Curve + Time Limit
Very Inverse Curve	Very Inverse Curve + Time Limit
Extremely Inverse Curve	Extremely Inverse Curve + Time Limit
Short-Term Inverse Curve	Short-Term Inverse Curve + Time Limit

RI Inverse Curve
User-Defined Curve
Fixed Time Characteristic

- **Overcurrent Elements: HMI Access (DLX-A Model)**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - OPEN POLE LOGIC
2 - ACTIVATE GROUP	2 - RECLOSER	**2 - OVERCURRENT**
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN PHASE DETECTOR
4 - INFORMATION	...	4 - CT SUPERVISION
		5 - THERMAL IMAGE
		6 - COLD LOAD
		7 - BREAKER FAILURE
		8 - POLE DISCREPANCY
		9 - PHASE SELECTOR
		10 - PROTECTION LOGIC

Time Overcurrent Elements

0 - LINE DIFFERENTIAL		**0 - PHASE TOC**
1 - OPEN POLE LOGIC	**0 - TIME OVERCURRENT**	**1 - NEGSEQ TOC**
2 - OVERCURRENT	1 - INSTANTANEOUS	**2 - GROUND TOC**
3 - OPEN PHASE DETECTOR		**3 - S.GROUND TIME**
4 - CT SUPERVISION		
...		

0 - PHASE TOC	**0 - UNIT 1**	**0 - PHASE TOC ENABLE**
1 - NEGSEQ TOC	**1 - UNIT 2**	**1 - PHASE TOC PICKUP**
2 - GROUND TOC	**2 - UNIT 3**	**2 - PHASE TOC CURVE**
3 - S.GROUND TIME		**3 - PHASE TOC DIAL**
		4 - PHASE TOC DELAY

0 - PHASE TOC	**0 - UNIT 1**	**0 - N.S. TOC Enable**
1 - NEGSEQ TOC	**1 - UNIT 2**	**1 - N.S. TOC Pickup**
2 - GROUND TOC	**2 - UNIT 3**	**2 - N.S. TOC Curve**
3 - S.GROUND TIME		**3 - N.S. TOC Dial**
		4 - N.S. TOC Delay

0 - PHASE TOC	**0 - UNIT 1**	**0 - GROUND TOC ENABLE**
1 - NEGSEQ TOC	**1 - UNIT 2**	**1 - GROUND TOC PICKUP**
2 - GROUND TOC	**2 - UNIT 3**	**2 - GROUND TOC CURVE**
3 - S.GROUND TIME		**3 - GROUND TOC DIAL**
		4 - GROUND TOC DELAY

0 - PHASE TOC	**0 - S.G.TIME ENABLE**
1 - NEGSEQ TOC	**1 - S.G. TIME PICKUP**
2 - GROUND TOC	**2 - S.G. CURVE**
3 - S.GROUND TIME	**3 - S.G.TIME DIAL**
	4 - S.G. FIXED TIME

Instantaneous Phase Overcurrent

0 - LINE DIFFERENTIAL		**0 - PHASE IOC**
1 - OPEN POLE LOGIC	0 - TIME OVERCURRENT	**1 - NEGSEQ IOC**
2 - OVERCURRENT	**1 - INSTANTANEOUS**	**2 - GROUND IOC**
3 - OPEN PHASE DETECTOR		**3 - S.GROUND INSTANT.**
4 - CT SUPERVISION		
...		

0 - PHASE IOC	**0 - UNIT 1**	**0 - PHASE IOC ENABLE**
1 - NEGSEQ IOC	**1 - UNIT 2**	**1 - PHASE IOC PICKUP**
2 - GROUND IOC	**2 - UNIT 3**	**2 - PHASE IOC DELAY**
3 - S.GROUND INSTANT.		

0 - PHASE IOC	**0 - UNIT 1**	**0 - N.S. IOC ENABLE**
1 - NEGSEQ IOC	**1 - UNIT 2**	**1 - N.S. IOC PICKUP**
2 - GROUND IOC	**2 - UNIT 3**	**2 - N.S. IOC DELAY**
3 - S.GROUND INSTANT.		

0 - PHASE IOC	**0 - UNIT 1**	**0 - GND IOC ENABLE**
1 - NEGSEQ IOC	**1 - UNIT 2**	**1 - GND IOC PICKUP**
2 - GROUND IOC	**2 - UNIT 3**	**2 - GND IOC DELAY**
3 - S.GROUND INSTANT.		

0 - PHASE IOC	
1 - NEGSEQ IOC	**0 - S.G. IOC ENABLE**
2 - GROUND IOC	**1 - S.G. IOC PICKUP**
3 - S.GROUND INSTANT.	**2 - S.G. IOC DELAY**

- **Overcurrent Elements: HMI Access (DLX-B Model)**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	**4 - OVERCURRENT**
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

Time Overcurrent Elements

0 - LINE DIFFERENTIAL		
1 - FUSE FAILURE		0 - PHASE TOC
2 - DEAD LINE DETECTOR	0 - DIRECTIONAL	1 - NEGSEQ TOC
3 - OPEN POLE LOGIC	**1 - TIME OVERCURRENT**	2 - GROUND TOC
4 - OVERCURRENT	2 - INSTANTANEOUS	3 - S.GROUND TIME
...		

0 - PHASE TOC	0 - UNIT 1	0 - PHASE TOC ENABLE
1 - NEGSEQ TOC	1 - UNIT 2	1 - PHASE TOC PICKUP
2 - GROUND TOC	2 - UNIT 3	2 - PHASE TOC CURVE
3 - S.GROUND TIME		3 - PHASE TOC DIAL
		4 - PHASE TOC DELAY
		5 - PH TOC DIRECTION

0 - PHASE TOC	0 - UNIT 1	0 - N.S. TOC ENABLE
1 - NEGSEQ TOC	1 - UNIT 2	1 - N.S. TOC PICKUP
2 - GROUND TOC	2 - UNIT 3	2 - N.S. TOC CURVE
3 - S.GROUND TIME		3 - N.S. TOC DIAL
		4 - N.S. TOC DELAY
		5 - N.S. TOC DIRECTION

0 - PHASE TOC	0 - UNIT 1	0 - GROUND TOC ENABLE
1 - NEGSEQ TOC	1 - UNIT 2	1 - GROUND TOC PICKUP
2 - GROUND TOC	2 - UNIT 3	2 - GROUND TOC CURVE
3 - S.GROUND TIME		3 - GROUND TOC DIAL
		4 - GROUND TOC DELAY
		5 - GND TOC DIRECTION
		6 - GROUN TOC DIR UNT

0 - PHASE TOC	0 - S.G.TIME ENABLE
1 - NEGSEQ TOC	1 - S.G. TIME PICKUP
2 - GROUND TOC	2 - S.G. CURVE
3 - S.GROUND TIME	3 - S.G.TIME DIAL
	4 - S.G. FIXED TIME
	5 - S.G. TOC DIRECTION

Instantaneous Phase Overcurrent

0 - LINE DIFFERENTIAL		
1 - FUSE FAILURE		**0 - PHASE TOC**
2 - DEAD LINE DETECTOR	0 - DIRECTIONAL	**1 - NEGSEQ TOC**
3 - OPEN POLE LOGIC	1 - TIME OVERCURRENT	**2 - GROUND TOC**
4 - OVERCURRENT	**2 - INSTANTANEOUS**	**3 - S.GROUND TIME**
…		

0 - PHASE TOC	**0 - UNIT 1**	**0 - PHASE IOC ENABLE**
1 - NEGSEQ IOC	**1 - UNIT 2**	**1 - PHASE IOC PICKUP**
2 - GROUND IOC	**2 - UNIT 3**	**2 - PHASE IOC DELAY**
3 - S.GROUND INSTANT.		**3 - PHASEIOC DIRECTION**

0 - PHASE IOC	**0 - UNIT 1**	**0 - N.S. IOC ENABLE**
1 - INSTA. SEC. INV.	**1 - UNIT 2**	**1 - N.S. IOC PICKUP**
2 - GROUND IOC	**2 - UNIT 3**	**2 - N.S. IOC DELAY**
3 - S.GROUND INSTANT.		**3 - N.S. IOC DIRECTION**

0 - PHASE IOC	**0 - UNIT 1**	**0 - GND IOC ENABLE**
1 - NEGSEQ IOC	**1 - UNIT 2**	**1 - GND IOC PICKUP**
2 - GROUND IOC	**2 - UNIT 3**	**2 - GND IOC DELAY**
3 - S.GROUND INSTANT.		**3 - GND IOC DIRECTION**
		4 - GND IOC DIREC UNIT

0 - PHASE IOC	**0 - S.G. IOC ENABLE**
1 - NEGSEQ IOC	**1 - S.G. IOC PICKUP**
2 - GROUND IOC	**2 - S.G. IOC DELAY**
3 - S.GROUND INSTANT.	**3 - S.G. IOC DIRECTION**

3.8.7 Digital Inputs and Events of the Overcurrent Modules

Table 3.8-1: Digital Inputs and Events of the Overcurrent Modules		
Name	**Description**	**Function**
INBLK_IOC_PH1	Phase IOC Element 1 Block Trip Input	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
INBLK_IOC_N1	Ground IOC Element 1 Block Trip Input	
INBLK_IOC_NS1	Negative Sequence IOC Element 1 Block Trip Input	
INBLK_IOC_PH2	Phase IOC Element 2 Block Trip Input	
INBLK_IOC_N2	Ground IOC Element 2 Block Trip Input	
INBLK_IOC_NS2	Negative Sequence IOC Element 2 Block Trip Input	
INBLK_IOC_PH3	Phase IOC Element 3 Block Trip Input	
INBLK_IOC_N3	Ground IOC Element 3 Block Trip Input	
INBLK_IOC_NS3	Negative Sequence IOC Element 3 Block Trip Input	
INBLK_IOC_SG	Sensitive Ground IOC Element Block Trip Input	
INBLK_TOC_PH1	Phase TOC Element 1 Block Trip Input	
INBLK_TOC_N1	Ground TOC Element 1 Block Trip Input	
INBLK_TOC_NS1	Negative Sequence TOC Element 1 Block Trip Input	
INBLK_TOC_PH2	Phase TOC Element 2 Block Trip Input	
INBLK_TOC_N2	Ground TOC Element 2 Block Trip Input	
INBLK_TOC_NS2	Negative Sequence TOC Element 2 Block Trip Input	
INBLK_TOC_PH3	Phase TOC Element 3 Block Trip Input	
INBLK_TOC_N3	Ground TOC Element 3 Block Trip Input	
INBLK_TOC_NS3	Negative Sequence TOC Element 3 Block Trip Input	
INBLK_TOC_SG	Sensitive Ground TOC Element Block Trip Input	
INRST_IOC_PH1	Phase IOC Element 1 Torque Annulment Input	It resets the element's timing functions and keeps them at 0 as long as it is active. With the element configured in directional mode, if the corresponding monitoring setting and the input are active, trip is blocked for lack of determining the direction.
IN_RST_IOC_N1	Ground IOC Element 1 Torque Annulment Input	
INRST_IOC_NS1	Negative Sequence IOC Element 1 Torque Annulment Input	
INRST_IOC_PH2	Phase IOC Element 2 Torque Annulment Input	
IN_RST_IOC_N2	Ground IOC Element 2 Torque Annulment Input	
INRST_IOC_NS2	Negative Sequence IOC Element 2 Torque Annulment Input	
INRST_IOC_PH3	Phase IOC Element 3 Torque Annulment Input	
IN_RST_IOC_N3	Ground IOC Element 3 Torque Annulment Input	
INRST_IOC_NS3	Negative Sequence IOC Element 3 Torque Annulment Input	
INRST_TOC_PH1	Phase TOC Element 1 Torque Annulment Input	
IN_RST_TOC_N1	Ground TOC Element 1 Torque Annulment Input	
INRST_TOC_NS1	Negative Sequence TOC Element 1 Torque Annulment Input	

Table 3.8-1: Digital Inputs and Events of the Overcurrent Modules		
Name	**Description**	**Function**
INRST_TOC_PH2	Phase TOC Element 2 Torque Annulment Input	It resets the element's timing functions and keeps them at 0 as long as it is active. With the element configured in directional mode, if the corresponding monitoring setting and the input are active, trip is blocked for lack of determining the direction.
IN_RST_TOC_N2	Ground TOC Element 2 Torque Annulment Input	
INRST_TOC_NS2	Negative Sequence TOC Element 2 Torque Annulment Input	
INRST_TOC_PH3	Phase TOC Element 3 Torque Annulment Input	
IN_RST_TOC_N3	Ground TOC Element 3 Torque Annulment Input	
INRST_TOC_NS3	Negative Sequence TOC Element 3 Torque Annulment Input	
IN_RST_TOC_SG	Sensitive Ground TOC Element Torque Annulment Input	
IN_BPT_PH1	Phase TOC Element 1 Bypass Time Input	It converts the set timing sequence of a given element to instantaneous.
IN_BPT_N1	Ground TOC Element 1 Bypass Time Input	
IN_BPT_NS1	Negative Sequence TOC Element 1 Bypass Time Input	
IN_BPT_PH2	Phase TOC Element 2 Bypass Time Input	
IN_BPT_N2	Ground TOC Element 2 Bypass Time Input	
IN_BPT_NS2	Negative Sequence TOC Element 2 Bypass Time Input	
IN_BPT_PH3	Phase TOC Element 3 Bypass Time Input	
IN_BPT_N3	Ground TOC Element 3 Bypass Time Input	
IN_BPT_NS3	Negative Sequence TOC Element 3 Bypass Time Input	
IN_BPT_SG	Sensitive Ground TOC Element Bypass Time Input	

Table 3.8-1: Digital Inputs and Events of the Overcurrent Modules

Name	Description	Function
ENBL_IOC_PH1	Phase IOC Element 1 Enable Input	Activation of this input puts the element into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”
ENBL_IOC_N1	Ground IOC Element 1 Enable Input	
ENBL_IOC_NS1	Negative Sequence IOC Element 1 Enable Input	
ENBL_IOC_PH2	Phase IOC Element 2 Enable Input	
ENBL_IOC_N2	Ground IOC Element 2 Enable Input	
ENBL_IOC_NS2	Negative Sequence IOC Element 2 Enable Input	
ENBL_IOC_PH3	Phase IOC Element 3 Enable Input	
ENBL_IOC_N3	Ground IOC Element 3 Enable Input	
ENBL_IOC_NS3	Negative Sequence IOC Element 3 Enable Input	
ENBL_IOC_SG	Sensitive Ground IOC Element Enable Input	
ENBL_TOC_PH1	Phase TOC Element 1 Enable Input	
ENBL_TOC_N1	Ground TOC Element 1 Enable Input	
ENBL_TOC_NS1	Negative Sequence TOC Element 1 Enable Input	
ENBL_TOC_PH2	Phase TOC Element 2 Enable Input	
ENBL_TOC_N2	Ground TOC Element 2 Enable Input	
ENBL_TOC_NS2	Negative Sequence TOC Element 2 Enable Input	
ENBL_TOC_PH3	Phase TOC Element 3 Enable Input	
ENBL_TOC_N3	Ground TOC Element 3 Enable Input	
ENBL_TOC_NS3	Negative Sequence TOC Element 3 Enable Input	
ENBL_TOC_SG	Sensitive Ground TOC Element 3 Enable Input	

3.8.8 Digital Outputs and Events of the Overcurrent Modules

Table 3.8-2: Digital Outputs and Events of the Overcurrent Modules		
Name	**Description**	**Function**
PU_IOC_A1	Phase A IOC Element 1 Pickup	AND logic of the pickup of the current elements with the corresponding torque control input.
PU_IOC_B1	Phase B IOC Element 1 Pickup	
PU_IOC_C1	Phase C IOC Element 1 Pickup	
PU_IOC_N1	Ground IOC Element 1 Pickup	
PU_IOC_NS1	Negative Sequence IOC Element 1 Pickup	
PU_IOC_A2	Phase A IOC Element 2 Pickup	
PU_IOC_B2	Phase B IOC Element 2 Pickup	
PU_IOC_C2	Phase C IOC Element 2 Pickup	
PU_IOC_N2	Ground IOC Element 2 Pickup	
PU_IOC_NS2	Negative Sequence IOC Element 2 Pickup	
PU_IOC_A3	Phase A IOC Element 3 Pickup	
PU_IOC_B3	Phase B IOC Element 3 Pickup	
PU_IOC_C3	Phase C IOC Element 3 Pickup	
PU_IOC_N3	Ground IOC Element 3 Pickup	
PU_IOC_NS3	Negative Sequence IOC Element 3 Pickup	
PU_IOC_SG	Sensitive Ground IOC Element Pickup	
PU_TOC_A1	Phase A TOC Element 1 Pickup	
PU_TOC_B1	Phase B TOC Element 1 Pickup	
PU_TOC_C1	Phase C TOC Element 1 Pickup	
PU_TOC_N1	Ground TOC Element 1 Pickup	
PU_TOC_NS1	Negative Sequence TOC Element 1 Pickup	
PU_TOC_A2	Phase A TOC Element 2 Pickup	
PU_TOC_B2	Phase B TOC Element 2 Pickup	
PU_TOC_C2	Phase C TOC Element 2 Pickup	
PU_TOC_N2	Ground TOC Element 2 Pickup	
PU_TOC_NS2	Negative Sequence TOC Element 2 Pickup	
PU_TOC_A3	Phase A TOC Element 3 Pickup	
PU_TOC_B3	Phase B TOC Element 3 Pickup	
PU_TOC_C3	Phase C TOC Element 3 Pickup	
PU_TOC_N3	Ground TOC Element 3 Pickup	
PU_TOC_NS3	Negative Sequence TOC Element 3 Pickup	
PU_TOC_SG	Sensitive Ground TOC Element Pickup	
PU_IOC	Instantaneous Elements Pickup (does not generate an event)	Pickup of the grouped current elements.
PU_TOC	Time Elements Pickup (does not generate an event)	

Table 3.8-2: Digital Outputs and Events of the Overcurrent Modules		
Name	**Description**	**Function**
CPU_IOC_A1	Phase A IOC Element 1 Pickup Conditions	Pickup of the current elements, unaffected by the torque control.
CPU_IOC_B1	Phase B IOC Element 1 Pickup Conditions	
CPU_IOC_C1	Phase C IOC Element 1 Pickup Conditions	
CPU_IOC_N1	Ground IOC Element 1 Pickup Conditions	
CPU_IOC_NS1	Negative Sequence IOC Element 1 Pickup Conditions	
CPU_IOC_A2	Phase A IOC Element 2 Pickup Conditions	
CPU_IOC_B2	Phase B IOC Element 2 Pickup Conditions	
CPU_IOC_C2	Phase C IOC Element 2 Pickup Conditions	
CPU_IOC_N2	Ground IOC Element 2 Pickup Conditions	
CPU_IOC_NS2	Negative Sequence IOC Element 2 Pickup Conditions	
CPU_IOC_A3	Phase A IOC Element 3 Pickup Conditions	
CPU_IOC_B3	Phase B IOC Element 3 Pickup Conditions	
CPU_IOC_C3	Phase C IOC Element 3 Pickup Conditions	
CPU_IOC_N3	Ground IOC Element 3 Pickup Conditions	
CPU_IOC_NS3	Negative Sequence IOC Element 3 Pickup Conditions	
CPU_IOC_SG	Sensitive Ground IOC Element Pickup Conditions	
CPU_TOC_A1	Phase A TOC Element 1 Pickup Conditions	
CPU_TOC_B1	Phase B TOC Element 1 Pickup Conditions	
CPU_TOC_C1	Phase C TOC Element 1 Pickup Conditions	
CPU_TOC_N1	Ground TOC Element 1 Pickup Conditions	
CPU_TOC_NS1	Negative Sequence TOC Element 1 Pickup Conditions	
CPU_TOC_A2	Phase A TOC Element 2 Pickup Conditions	
CPU_TOC_B2	Phase B TOC Element 2 Pickup Conditions	
CPU_TOC_C2	Phase C TOC Element 2 Pickup Conditions	
CPU_TOC_N2	Ground TOC Element 2 Pickup Conditions	

Table 3.8-2: Digital Outputs and Events of the Overcurrent Modules		
Name	**Description**	**Function**
CPU_TOC_NS2	Negative Sequence TOC Element 2 Pickup Conditions	Pickup of the current elements, unaffected by the torque control.
CPU_TOC_A3	Phase A TOC Element 3 Pickup Conditions	
CPU_TOC_B3	Phase B TOC Element 3 Pickup Conditions	
CPU_TOC_C3	Phase C TOC Element 3 Pickup Conditions	
CPU_TOC_N3	Ground TOC Element 3 Pickup Conditions	
CPU_TOC_NS3	Negative Sequence TOC Element 3 Pickup Conditions	
CPU_TOC_SG	Sensitive Ground TOC Element Pickup Conditions	
TRIP_IOC_A1	Phase A IOC Element 1 Trip	Trip of the current elements.
TRIP_IOC_B1	Phase B IOC Element 1 Trip	
TRIP_IOC_C1	Phase C IOC Element 1 Trip	
TRIP_IOC_N1	Ground IOC Element 1 Trip	
TRIP_IOC_NS1	Negative Sequence IOC Element 1 Trip	
TRIP_IOC_A2	Phase A IOC Element 2 Trip	
TRIP_IOC_B2	Phase B IOC Element 2 Trip	
TRIP_IOC_C2	Phase C IOC Element 2 Trip	
TRIP_IOC_N2	Ground IOC Element 2 Trip	
TRIP_IOC_NS2	Negative Sequence IOC Element 2 Trip	
TRIP_IOC_A3	Phase A IOC Element 3 Trip	
TRIP_IOC_B3	Phase B IOC Element 3 Trip	
TRIP_IOC_C3	Phase C IOC Element 3 Trip	
TRIP_IOC_N3	Ground IOC Element 3 Trip	
TRIP_IOC_NS3	Negative Sequence IOC Element 3 Trip	
TRIP_IOC_SG	Sensitive Ground IOC Element Trip	
TRIP_TOC_A1	Phase A TOC Element 1 Trip	
TRIP_TOC_B1	Phase B TOC Element 1 Trip	
TRIP_TOC_C1	Phase C TOC Element 1 Trip	
TRIP_TOC_N1	Ground TOC Element 1 Trip	
TRIP_TOC_NS1	Negative Sequence TOC Element 1 Trip	
TRIP_TOC_A2	Phase A TOC Element 2 Trip	
TRIP_TOC_B2	Phase B TOC Element 2 Trip	
TRIP_TOC_C2	Phase C TOC Element 2 Trip	
TRIP_TOC_N2	Ground TOC Element 2 Trip	
TRIP_TOC_NS2	Negative Sequence TOC Element 2 Trip	
TRIP_TOC_A3	Phase A TOC Element 3 Trip	
TRIP_TOC_B3	Phase B TOC Element 3 Trip	
TRIP_TOC_C3	Phase C TOC Element 3 Trip	
TRIP_TOC_N3	Ground TOC Element 3 Trip	
TRIP_TOC_NS3	Negative Sequence TOC Element 3 Trip	
TRIP_TOC_SG	Sensitive Ground TOC Element Trip	
TRIP_IOC	Instantaneous Elements Trips (does not generate an event)	Trip of the grouped current elements.
TRIP_TOC	Time Elements Trips (does not generate an event)	

Table 3.8-2: Digital Outputs and Events of the Overcurrent Modules		
Name	**Description**	**Function**
IOC_PH1_ENBLD	Phase IOC Element 1 Enabled	Indication of enabled or disabled status of the current elements.
IOC_N1_ENBLD	Ground IOC Element 1 Enabled	
IOC_NS1_ENBLD	Negative Sequence IOC Element 1 Enabled	
IOC_PH2_ENBLD	Phase IOC Element 2 Enabled	
IOC_N2_ENBLD	Ground IOC Element 2 Enabled	
IOC_NS2_ENBLD	Negative Sequence IOC Element 2 Enabled	
IOC_PH3_ENBLD	Phase IOC Element 3 Enabled	
IOC_N3_ENBLD	Ground IOC Element 3 Enabled	
IOC_NS3_ENBLD	Negative Sequence IOC Element 3 Enabled	
IOC_SG_ENBLD	Sensitive Ground IOC Element Enabled	
TOC_PH1_ENBLD	Phase TOC Element 1 Enabled	
TOC_N1_ENBLD	Ground TOC Element 1 Enabled	
TOC_NS1_ENBLD	Negative Sequence TOC Element 1 Enabled	
TOC_PH2_ENBLD	Phase TOC Element 2 Enabled	
TOC_N2_ENBLD	Ground TOC Element 2 Enabled	
TOC_NS2_ENBLD	Negative Sequence TOC Element 2 Enabled	
TOC_PH3_ENBLD	Phase TOC Element 3 Enabled	
TOC_N3_ENBLD	Ground TOC Element 3 Enabled	
TOC_NS3_ENBLD	Negative Sequence TOC Element 3 Enabled	
TOC_SG_ENBLD	Sensitive Ground TOC Element Enabled	
INBLK_IOC_PH1	Phase IOC Element 1 Block Trip Input	The same as for the digital inputs.
INBLK_IOC_N1	Ground IOC Element 1 Block Trip Input	
INBLK_IOC_NS1	Negative Sequence IOC Element 1 Block Trip Input	
INBLK_IOC_PH2	Phase IOC Element 2 Block Trip Input	
INBLK_IOC_N2	Ground IOC Element 2 Block Trip Input	
INBLK_IOC_NS2	Negative Sequence IOC Element 2 Block Trip Input	
INBLK_IOC_PH3	Phase IOC Element 3 Block Trip Input	
INBLK_IOC_N3	Ground IOC Element 3 Block Trip Input	
INBLK_IOC_NS3	Negative Sequence IOC Element 3 Block Trip Input	
INBLK_IOC_SG	Sensitive Ground IOC Element Block Trip Input	
INBLK_TOC_PH1	Phase TOC Element 1 Block Trip Input	
INBLK_TOC_N1	Ground TOC Element 1 Block Trip Input	
INBLK_TOC_NS1	Negative Sequence TOC Element 1 Block Trip Input	
INBLK_TOC_PH2	Phase TOC Element 2 Block Trip Input	
INBLK_TOC_N2	Ground TOC Element 2 Block Trip Input	
INBLK_TOC_NS2	Negative Sequence TOC Element 2 Block Trip Input	
INBLK_TOC_PH3	Phase TOC Element 3 Block Trip Input	
INBLK_TOC_N3	Ground TOC Element 3 Block Trip Input	
INBLK_TOC_NS3	Negative Sequence TOC Element 3 Block Trip Input	
INBLK_TOC_SG	Sensitive Ground TOC Element Block Trip Input	

Table 3.8-2: Digital Outputs and Events of the Overcurrent Modules		
Name	**Description**	**Function**
INRST_IOC_PH1	Phase IOC Element 1 Torque Annulment Input	The same as for the digital inputs.
IN_RST_IOC_N1	Ground IOC Element 1 Torque Annulment Input	
INRST_IOC_NS1	Negative Sequence IOC Element 1 Torque Annulment Input	
INRST_IOC_PH2	Phase IOC Element 2 Torque Annulment Input	
IN_RST_IOC_N2	Ground IOC Element 2 Torque Annulment Input	
INRST_IOC_NS2	Negative Sequence IOC Element 2 Torque Annulment Input	
INRST_IOC_PH3	Phase IOC Element 3 Torque Annulment Input	
IN_RST_IOC_N3	Ground IOC Element 3 Torque Annulment Input	
INRST_IOC_NS3	Negative Sequence IOC Element 3 Torque Annulment Input	
INRST_IOC_SG	Sensitive Ground Sequence IOC Element Torque Annulment Input	
INRST_TOC_PH1	Phase TOC Element 1 Torque Annulment Input	
IN_RST_TOC_N1	Ground TOC Element 1 Torque Annulment Input	
INRST_TOC_NS1	Negative Sequence TOC Element 1 Torque Annulment Input	
INRST_TOC_PH2	Phase TOC Element 2 Torque Annulment Input	
IN_RST_TOC_N2	Ground TOC Element 2 Torque Annulment Input	
INRST_TOC_NS2	Negative Sequence TOC Element 2 Torque Annulment Input	
INRST_TOC_PH3	Phase TOC Element 3 Torque Annulment Input	
IN_RST_TOC_N3	Ground TOC Element 3 Torque Annulment Input	
INRST_TOC_NS3	Negative Sequence TOC Element 3 Torque Annulment Input	
INRST_TOC_SG	Sensitive Ground Sequence TOC Element Torque Annulment Input	

Table 3.8-2: Digital Outputs and Events of the Overcurrent Modules		
Name	**Description**	**Function**
IN_BPT_PH1	Phase TOC Element 1 Bypass Time Input	It converts the set timing sequence of a given element to instantaneous.
IN_BPT_N1	Ground TOC Element 1 Bypass Time Input	
IN_BPT_NS1	Negative Sequence TOC Element 1 Bypass Time Input	
IN_BPT_PH2	Phase TOC Element 2 Bypass Time Input	
IN_BPT_N2	Ground TOC Element 2 Bypass Time Input	
IN_BPT_NS2	Negative Sequence TOC Element 2 Bypass Time Input	
IN_BPT_PH3	Phase TOC Element 3 Bypass Time Input	
IN_BPT_N3	Ground TOC Element 3 Bypass Time Input	
IN_BPT_NS3	Negative Sequence TOC Element 3 Bypass Time Input	
IN_BPT_SG	Sensitive Ground TOC Element Bypass Time Input	
ENBL_IOC_PH1	Phase IOC Element 1 Enable Input	The same as for the digital inputs.
ENBL_IOC_N1	Ground IOC Element 1 Enable Input	
ENBL_IOC_NS1	Negative Sequence IOC Element 1 Enable Input	
ENBL_IOC_PH2	Phase IOC Element 2 Enable Input	
ENBL_IOC_N2	Ground IOC Element 2 Enable Input	
ENBL_IOC_NS2	Negative Sequence IOC Element 2 Enable Input	
ENBL_IOC_PH3	Phase IOC Element 3 Enable Input	
ENBL_IOC_N3	Ground IOC Element 3 Enable Input	
ENBL_IOC_NS3	Negative Sequence IOC Element 3 Enable Input	
ENBL_IOC_SG	Sensitive Ground IOC Element Enable Input	

Table 3.8-2: Digital Outputs and Events of the Overcurrent Modules		
Name	**Description**	**Function**
ENBL_TOC_PH1	Phase TOC Element 1 Enable Input	The same as for the digital inputs.
ENBL_TOC_N1	Ground TOC Element 1 Enable Input	
ENBL_TOC_NS1	Negative Sequence TOC Element 1 Enable Input	
ENBL_TOC_PH2	Phase TOC Element 2 Enable Input	
ENBL_TOC_N2	Ground TOC Element 2 Enable Input	
ENBL_TOC_NS2	Negative Sequence TOC Element 2 Enable Input	
ENBL_TOC_PH3	Phase TOC Element 3 Enable Input	
ENBL_TOC_N3	Ground TOC Element 3 Enable Input	
ENBL_TOC_NS3	Negative Sequence TOC Element 3 Enable Input	
ENBL_TOC_SG	Sensitive Ground TOC Element Enable Input	

3.8.9 Overcurrent Elements Test

It is recommended that the overcurrent units be tested one by one, disabling those that are not being tested at any given time. For this test, the directionality of the IED should be annulled to not depend on the voltages (setting **Enable Pickup Blocking** or **Torque Control** to **NO**). Otherwise, they must be injected so the units will be in the trip enable zone.

- **Pickup and Reset**

The desired pickup values for the relevant unit must be set and its activation checked by operating any output configured for this purpose. This can also be verified by checking the pickup flags of the menu **Information - Status - Measuring Elements - Overcurrent**. It can also be checked that the trip flag of this menu is activated if the unit trips.

Table 3.8-3: Pickup and Reset of the Overcurrent Elements				
Setting of the unit	Pickup		Reset	
	Maximum	Minimum	Maximum	Minimum
X	1.08 **x** X	1.02 **x** X	1.03 **x** X	0.97 **x** X

In the low ranges, the pickup and reset interval can be extended up to X ± (5% x In) mA.

- **Operating Times**

They are verified with trip outputs C1-C2.

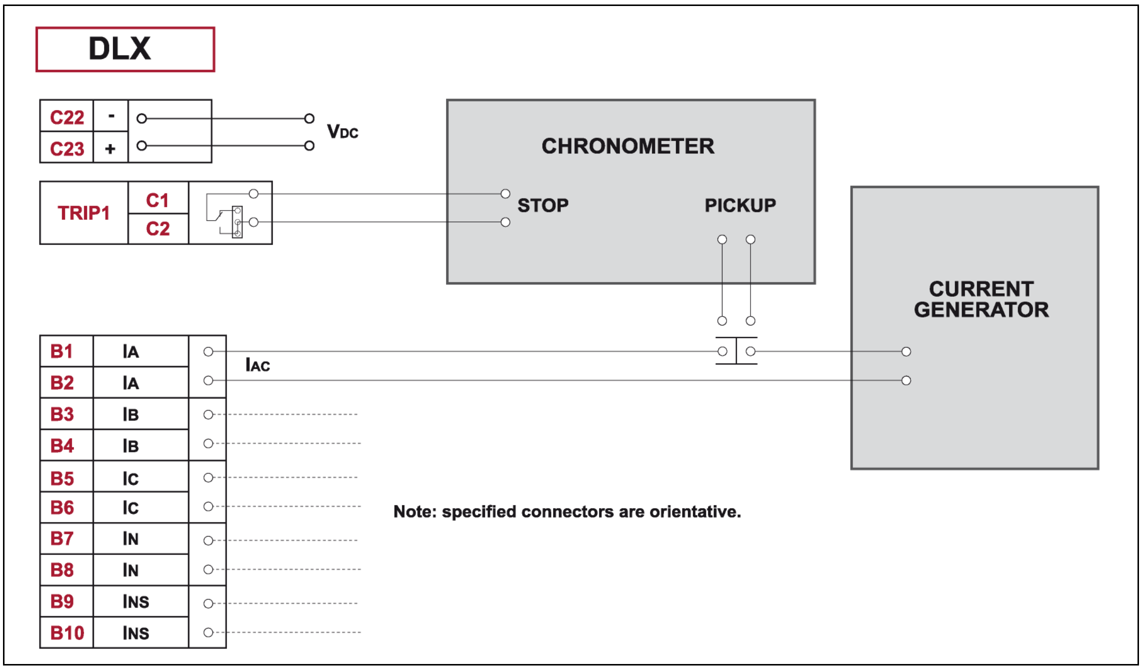

Figure 3.8.25 Operating Time Test Setup.

Fixed Time or Instantaneous

The pickup setting is increased 20%. Operating time should be the selected time setting ±1% or ±20 ms (whichever is greater). A setting of 0 ms will have an operating time between 20 and 25 ms.

Inverse Time

For a given curve, the operating time is determined by the time dial setting and the current applied (number of times of the pickup setting value). The tolerance is determined by applying a margin of error of ±1% in the current measurement. This means an error of ±2% or ±20 ms (whichever is greater) in the measuring times.

The operating times for the marked curves can be verified in the **DLX** model in section 3.8.2.

3.9 Directional Elements

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3.9.1 Introduction

DLX-B relays are provided with the following Directional Elements for overcurrent element control:

- One Directional Phase Element (67).
- One Directional Ground Element (67N).
- One Directional Sensitive Ground Element (67Ns).
- One Directional Negative Sequence Element (67Q).

The mission of the Directional Element is to determine the direction in which the operating current is flowing in order to control its associated Overcurrent Element. The direction is determined by comparing its phase with that of a reference value, the phase of which is maintained irrespective of the direction of the flow of the operating current.

Each Directional Element controls the corresponding Overcurrent Elements as long as the **Torque Control** setting is other than **Zero**. The control over the Overcurrent Element is carried out inhibiting the operation of the pickup elements in case the current flows in the reverse direction to that selected. If the Directional Element inhibits the operation of the Overcurrent Element, the timing function will not start. If the inhibition occurs once the timing has started, it will reset so that the timing will start again from zero if the inhibition disappears. In any case, a trip requires the timing function to be uninterrupted.

If the **Torque Control** is equal to **Zero**, the directional control is inhibited and allows the pickup of the Overcurrent Elements for current flows in both directions: direction and reverse direction.

In all cases, the Directional Element can enable and block trips in both directions (direction and reverse direction) with the **Torque Control** setting (**1** for the direction and **2** for the reverse direction). With **Torque Annulment** input activated, the corresponding directional element is not allowed to pick up.

The **Trip Direction Reversal** input (**IN_INV_TRIP**) changes, if activated, the direction of operation of all the Directional Elements.

All the Directional Elements generate **Direction** and **Reverse Direction** outputs, instantaneous as well as timed, which exercise directional control over the Instantaneous and Time Overcurrent Elements, respectively. The timing of the timed outputs of the Directional Elements is given by the **Coordination Time** setting.

The **Coordination Time** setting is applicable when teleprotection schemes are used in Permissive Overreach for Time Overcurrent Units, created through the **Timing Annulment** input associated with these elements. The following wiring should be carried out for this: pickup output of the time elements to the channel activation input of the teleprotection equipment and channel reception output of the teleprotection equipment to the timer annulment input of the time element.

The **Coordination Time** avoids erroneous trips in case of current reversal produced in double circuits. We consider the case of two parallel lines; the detection of a fault and its subsequent sequential trip in one of these may cause current reversal of one of the terminals of the parallel line, started as a result of this fault. In this case, the directional element will reverse its status and will go on not to allow the trip. If because of the Permissive Overreach the timer is annulled, an instantaneous trip will be produced, since the channel reception signal has a reset time other than zero. To prevent this possibility, the Coordination time may be used, which delays the application of the directional permission until the channel reception signal has disappeared. This delay only affects the time elements, provided that they are configured as directional.

Note: protection schemes associated to overcurrent elements (see 3.10) already include a Coordination Time setting separate from the one commented in this paragraph. The protection schemes can be associated to any Overcurrent Element whether instantaneous or time delayed. If time delayed elements are used, two coordination times must be considered (directional element setting and protection scheme setting).

3.9.2 Directional Phase Element

There is a Directional Element for each of the phases. In any one of them, the operating value is the phase current and the polarization value is the line voltage corresponding to the other two phases memorized 2 cycles before the pickup.

Figure 3.9.1 presents the vector diagram which shows the operating principle of the Directional Phase Elements.

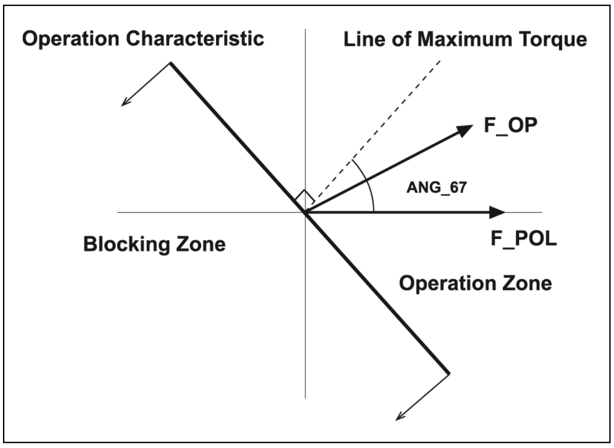

Figure 3.9.1 Vector Diagram of the Directional Phase Element.

The Phase Directional Elements check that the current and the voltages of the phases are above certain values. This value is adjustable for the voltage (**Minimum Phase Voltage** setting) and 0.02 In (with In being the rated current of the IED) for the current. If currents and voltages do not exceed their threshold values the above mentioned checking criterion is discontinued, signal **No Phase Polarization** (**LP_DIR_PH**) is activated and the **Lack of Polarization Blocking** setting is checked. If this setting indicates that there is **NO** blocking, the procedure is the same as for inhibiting the directional element. If, however, it indicates blocking by lack of polarization, trips in both directions are blocked.

Following table shows the operating and polarization values applied to each of the three phases.

Table 3.9-1: Phase Directional Element			
ABC Phases Sequence			
Phase	**Fop**	**Fpol**	**Criteria**
A	I_A	$U_{BCM} = (V_B - V_C)_M$	$-(90^{\circ} - ANG\_67) \leq [\arg(Fop) - \arg(Fpol)] \leq (90^{\circ} + ANG\_67)$
B	I_B	$U_{CAM} = (V_C - V_A)_M$	
C	I_C	$U_{ABM} = (V_A - V_B)_M$	
ACB Phases Sequence			
Phase	**Fop**	**Fpol**	**Criteria**
A	I_A	$U_{CBM} = (V_C - V_B)_M$	$-(90^{\circ} - ANG\_67) \leq [\arg(Fop) - \arg(Fpol)] \leq (90^{\circ} + ANG\_67)$
B	I_B	$U_{ACM} = (V_A - V_C)_M$	
C	I_C	$U_{BAM} = (V_B - V_A)_M$	

Drawn on a polar plot, the operation characteristic is a straight line the perpendicular of which (line of maximum torque) is rotated a certain angle counter clockwise, called characteristic angle, with respect to the polarization value. This straight line divides the plane into two semiplanes. This characteristic angle is the complementary to the angle of the positive sequence line impedance (see the Example of Application).

The Directional Element, if configured in direction, enables the Overcurrent Element when the above criteria is fulfilled (operation zone indicated in the diagram), while if configured in reverse direction, it enables the Overcurrent Element when this criteria is not fulfilled (blocking zone indicated in the diagram). As already mentioned, directional control is phase by phase.

The logic diagram of operation of the phase directional element is shown in Figure 3.9.2

The activation of the **Phase Directional Element Inhibition** (**INH_DIR_PH**) input converts the element to **Non-Directional**.

The **Inversion of the Trip Direction** (**IN_INV_TRIP**) input changes, if activated, the direction of operation of the Directional Element.

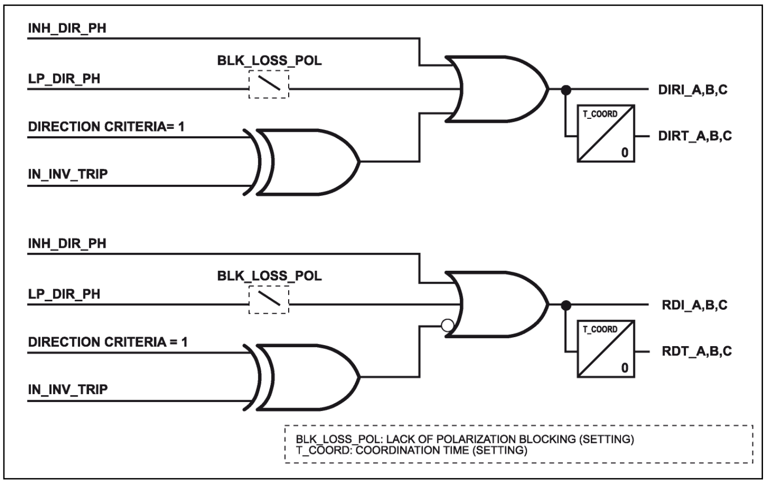

Figure 3.9.2 Block Diagram of a Directional Phase Element.

3.9.2.a Example of Application

This section will analyze the setting value of the characteristic angle for the phases with respect to the polarization magnitude that the IED uses to establish the line of maximum torque. This gives rise to the operation and blocking zones of the Phase Differential Elements in **Direction** mode.

The simplest case is a three-phase line open at one of its ends. Suppose a single-phase fault of phase A to ground and without default impedance. If the impedance of the line is **Zl**α, the current $\mathbf{I_A}$ that will flow through the fault will be generated by the presence of voltage $\mathbf{V_A}$ and delayed with respect to it, an angle α.

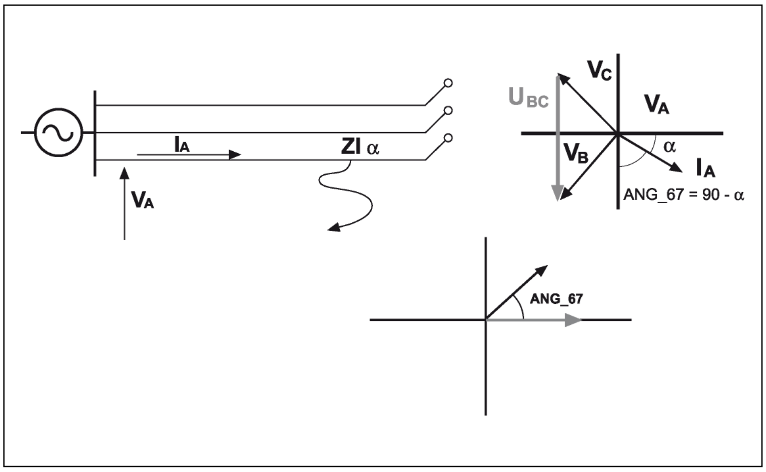

Figure 3.9.3 Graphics for the Example of Application.

DLX IEDs with Directional Elements for the phases do not use the simple voltage currents as polarization value for each of their corresponding operating values (the currents of each phase). The polarization values used are the phase-to-phase voltages between the other two phases not involved in the possible single-phase fault.

As the graphics show, for a fault in phase A like the one described initially, the polarization value that the IED uses to decide whether or not there is a trip is voltage $U_{BC} = V_B - V_C$, which is delayed in quadrature with respect to the simple voltage of faulted phase V_A.

Given that the characteristic angle (**ANG_67**) that adjusts to the IED is that which is between the operation value and the polarization value (see figure 3.9.1), the value assigned to it must be the angle complementary to the angle of the "impedance of the line". Everything said so far for phase A can be extrapolated directly for phases B and C.

In conclusion, if the impedance of the line is **Zl**α, the characteristic angle (**ANG_67**) that must be adjusted for the phases is: **ANG_67 = 90 -** α.

3.9.3 Directional Ground Element

Ground And Sensitive Ground Directional Element operation is based on zero-sequence and ground magnitudes. Zero-sequence current is taken as operate magnitude (measured through ground and sensitive ground channel).

Polarization magnitudes to be considered will depend on the units enabled:

- **Ground Directional Unit**: This can be polarized by the zero-sequence voltage (V0) or by the grounding current.

- **Sensitive Ground Directional Unit**: This unit can only be polarized by the zero-sequence voltage (V0).

The reason for both polarization magnitudes is next:

- **Zero-Sequence Voltage:** Zero-sequence voltage (V0) is calculated from phase voltages as follows:

$$\overline{V_0} = \frac{\overline{V_A} + \overline{V_B} + \overline{V_C}}{3}$$

- **Current Flow by Ground Fault**

In this case, there are two operation characteristics, one corresponding to each of the two modes, which, when drawn on a polar plot, are straight lines, each of which divides the plane into two semiplanes. The location of the operating value determines the output of the Directional Element and its action on the Overcurrent Element.

3.9.3.a Polarization by Voltage

In this case, the operating principle of the Ground Directional Element rests on the determination of the phase difference between the zero sequence current and a "compensated" zero sequence voltage based on **the Zero Sequence Voltage Compensation Factor** (K_{COMP_67N}).setting. Figure 3.9.4 diagrams the elements used to explain how polarization by voltage works.

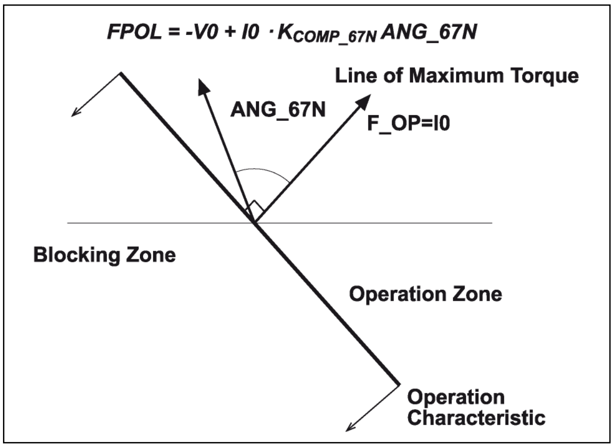

Figure 3.9.4 Vector Diagram of the Directional Ground Element (Polarization by Voltage).

The directional ground element checks that the polarization and operations phasors are above a certain value. This value is adjustable for the polarization phasor (**Minimum Zero Sequence Voltage** setting) and **0.02 In** (with **In** being the rated current of the IED) for the operation phasor. If the operation or polarization phasors do not exceed the threshold values, the **No Ground Polarization** (**LP_DIR_N**) signal will be activated and **Lack of Polarization Blocking** setting is shown. If this setting indicates that there is NO blocking, the procedure is the same as for inhibiting the directional element. If, however, it indicates blocking due to lack of polarization, trips in both directions are blocked.

The following table shows the operation and polarization phasors which intervene in the ground directional element, as well as the operation criteria applied.

Table 3.9-2:Directional Ground Element (polarization by voltage)

Fop	Fpol	Criteria
I0	$-V0+I0\cdot K_{COMP\_67N}\angle ANG\_67N$	$-(90^{\circ}+ANG\_67N)\leq[\arg(Fop)-\arg(Fpol)]\leq(90^{\circ}-ANG\_67N)$

Note: The residual ground directional element will not take into account the zero sequence voltage compensation factor (K_{COMP_67N}).

The Directional Element, if configured in direction, enables the Overcurrent Element when the previous criteria is fulfilled (operation zone indicated in the diagram), while if configured in reverse direction, it enables the Overcurrent Element when this criteria is not fulfilled (blocking zone indicated in the diagram).

Figures 3.9.5 and 3.9.6 show the zero sequence network for a ground fault (single phase or two phase) in a forward and reverse direction, respectively.

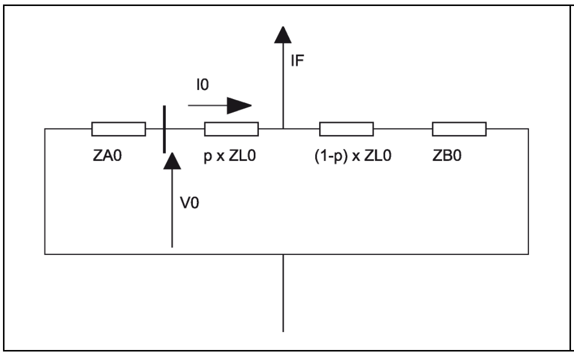

Figure 3.9.5 Zero Sequence Network for Forward Fault.

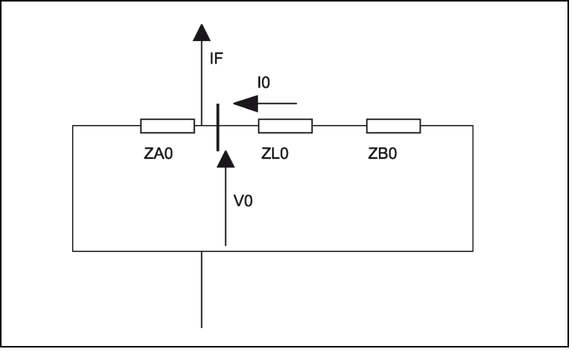

Figure 3.9.6 Zero Sequence Network for Reverse Fault.

If the fault is in forward direction, it can be deduced that $V0 = ZA0 \cdot (-I0)$, where $ZA0$ is the zero sequence impedance of the local source. It is seen, consequently, that the angle between $-V0$ and $I0$ will be that corresponding to this impedance. For this reason, this should be the characteristic angle of the ground directional element (**ANG_67N** setting).

If the fault is in the reverse direction, the following expression will be obtained: $V0 = (ZL0 + ZB0) \cdot I0$, where $ZL0$ and $ZB0$ are the zero sequence impedance of the line and the remote source, respectively. Consequently, the angle between $-V0$ and $I0$ will be supplementary of the angle of $ZL0 + ZB0$ impedance (which will be similar to the $ZA0$ angle).

Through the relative phase difference between $-V0$ and $I0$, the directionality of the fault can be deduced. However, the K_{COMP_67N} factor is used for the following two reasons:

Increase the polarization phasor magnitude, in order that this exceeds the **Minimum Zero Sequence Voltage**:

When the zero sequence impedance of the local source is small, in case of forward fault, the $V0$ voltage which measures the relay may present values under the **Minimum Zero Sequence Voltage** setting [it was previously deduced that $V0 = ZA0 \cdot (-I0)$]. In order to have sufficient voltage to polarize the ground directional element, a new voltage with the same phase is added to the $-V0$ phasor, which will correspond to the voltage drop in an impedance with **ANG_67N** angle (it is assumed that this adjustment will be equal to the $ZA0$ angle) and with a magnitude equal to K_{COMP_67N}. The effect of the new polarization phasor is that of expanding the zero sequence impedance magnitude of the local source with a value equal to K_{COMP_67N}.

The K_{COMP_67N} value should be restricted in order that the ground directional element does not take any erroneous directional decisions in case of faults in the reverse direction. When the fault is in the reverse direction $V0 = (ZL0 + ZB0) \cdot I0$, as was deduced previously. If we assume that the $ZL0 + ZB0$ angle is similar to the **ANG_67N** setting (assumption equal to $ZA0$ angle), $-V0$ and $I0 \cdot K_{COMP\_67N}$ will be in anti-phase, for which the sum of $I0 \cdot K_{COMP\_67N}$ reduces the polarization phasor value, with it being possible to even reverse its direction. The latter would occur if $K_{COMP\_67N} > (ZL0 + ZB0)$; in this case, the directional element would consider that the fault is in forward direction. For this reason, the K_{COMP_67N} value is restricted by the $ZL0 + ZB0$ value.

Compensate the inversion that the V0 voltage may undergo in lines with series compensation:

In case of faults in a forward direction, in a line with series compensation, $V0$ will be reversed (approximately 180º considering that the angle of source impedance is close to 90º), provided that the zero sequence impedance existing between the voltage transformer and the local source is capacitive. In this case, the directional element will act erroneously since it will consider that the fault is in the reverse direction. In order to rotate the reversed $-V0$ voltage 180º, such that the directional element can see the fault in a forward direction, a K_{COMP_67N} factor should be applied whose value exceeds the capacitive reactance value introduced. Notwithstanding, and in order to avoid erroneous directional decisions in case of reverse directional faults, as was indicated previously, K_{COMP_67N} should be less than $ZL0 + ZB0$ (impedance existing between the voltage transformer and the remote source).

3.9.3.b Polarization by Current

Determining the phase displacement between the residual current and the current circulating through the grounding is simple because the phase displacements between the two magnitudes can only be 0º and 180º or, what is the same, the characteristic angle must always be 0º.

When it is configured in direction, the operation zone is the zone in which the fault or operating current **In** is rotated 180º with respect to the current flowing through the grounding. As in the figure, **F_POL** is equal to the current flowing through the grounding rotated 180º. Therefore, **F_POL** and **In** must be in phase to be in the operation zone. When it is configured in reverse direction, it enables the overcurrent element in the opposite semiplane. Figure 3.13.7 shows the vector diagram associated with the ground directional element when the polarization by current is used.

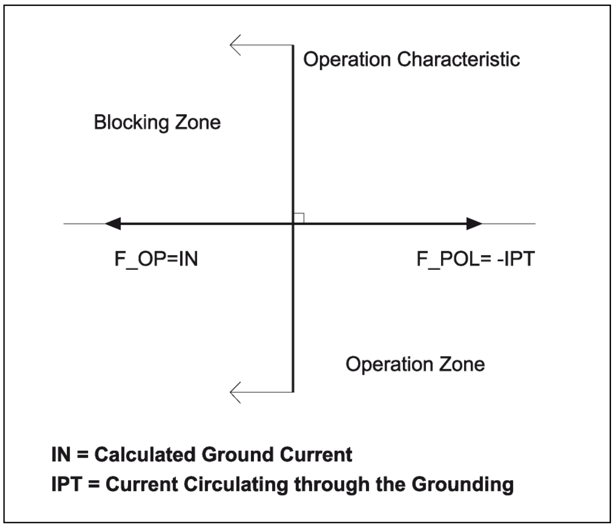

Figure 3.9.7 Vector Diagram of the Directional Ground Element (Polarization by Current).

The following table shows the operation and polarization phasors which intervenes in the ground directional element, as well as the operation criteria applied.

Table 3.9-3:Directional Ground Element (Polarization by Current)		
Fop	**Fpol**	**Criteria**
I0	-IPT	$-90^{\circ} \leq \arg(F\_OP) - \arg(F\_POL) \leq 90^{\circ}$

The Directional Element, if configured in direction, enables the Overcurrent Element when the previous criteria is fulfilled (operation zone indicated in the diagram), while if configured in reverse direction, it enables the Overcurrent Element when this criteria is not fulfilled (blocking zone indicated in the diagram).

3.9.3.c Polarization by Voltage and Current

If both polarizations coexist, the criterion is the following: If the Directional Ground Element is not inhibited, it checks that the current is above a minimum value. If it does not exceed this, the **No Ground Polarization** (**LP_DIR_N**) signal is activated and the **Lack of Polarization Blocking** setting is shown. If this setting indicates that there is **NO** blocking, the procedure is the same as for inhibiting the Directional Element. If, however, it indicates trip blocking, trips in both directions are blocked.

If it is above the minimum value, it checks that the polarization current is above a given value. If it is, it determines whether or not there is trip direction. If the **Direction Inversion Input** (**IN_INV_TRIP**) is active, the calculated direction is changed.

If the polarization by current solves the directionality (enables trip), the element does not check polarization by voltage. If the polarization by current does not solve the directionality, the element verifies that the polarization voltage is above a given adjustable value (**Ground Minimum Voltage**). If this is not the case, the **No Ground Polarization** (**LP_DIR_N**) signal is activated and the **Lack of Polarization Blocking** setting is shown. If this setting indicates that there is **NO** blocking, the procedure is the same as for inhibiting the Directional Element. If, however, it indicates trip blocking, trips in both directions are blocked.

The logic diagram of operation of the ground directional element is shown in Figure 3.9.8.

If the voltage level is correct, it is determined if there is trip direction according to the criteria indicated. If the **Direction Inversion Input** (**IN_INV_TRIP**) input is active, the direction of the calculated direction is changed.

The activation of the **Directional Ground Element Inhibit** (**INH_DIR_N**) input converts the element to non-directional.

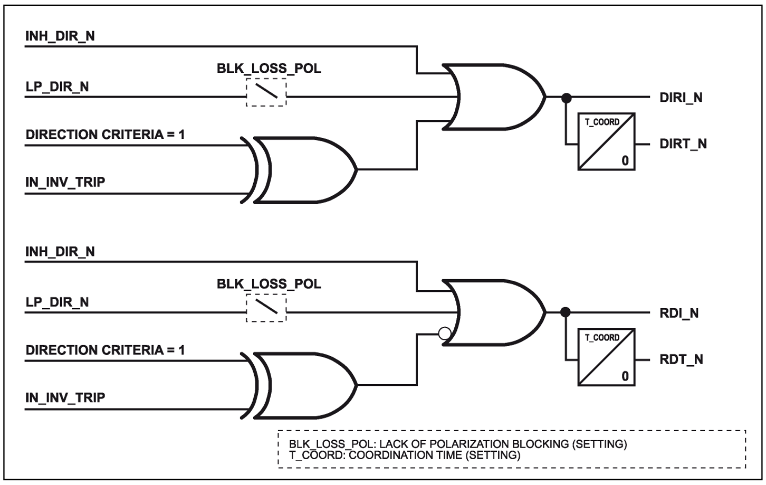

Figure 3.9.8 Block Diagram of a Directional Ground Element.

3.9.4 Directional Negative Sequence Element

The operating principle of a Directional Negative Sequence Element rests on the determination of the relative phase difference between the negative sequence current and a “compensated” negative sequence voltage based on the **Negative Sequence Voltage Compensation Factor** (K_{COMP_67Q}) setting. Figure 3.9.9 presents the vector diagram associated with the Directional Negative Sequence Element.

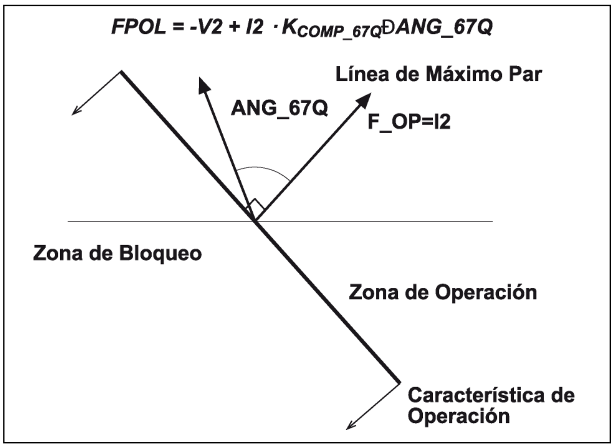

Figure 3.9.9 Vector Diagram of the Directional Negative Sequence Element.

The Directional Negative Sequence Element verifies that the operation and polarization phasors exceed certain determined values. This value is adjustable for the polarization phasor (**Minimum Negative Sequence Voltage** setting) and **0.02 In** (with **In** being the rated current of the IED) for the operation phasor. If the operation or polarization phasors do not exceed the threshold values, the **No Negative Sequence Polarization** (**LP_DIR_NS**) signal will be activated and the **Lack of Polarization Blocking due to** setting is shown. If this setting indicates that there is **NO** blocking, the same procedure as in case of directional inhibition is carried out; but if it indicates **Blocking Due to Lack of Polarization**, the trips in both directions are blocked.

The following table shows the operation and polarization phasors which intervene in the Directional Negative Sequence Element, as well as the operation criteria applied.

Table 3.9-4: Directional Negative Sequence Element		
Fop	**Fpol**	**Criteria**
I2	$-V2+I2\cdot K_{COMP\_67Q}\angle ANG\_67Q$	$-(90^{o}+ANG\_67Q)\leq[\arg(Fop)-\arg(Fpol)]\leq(90^{o}-ANG\_67Q)$

The Directional Element, if configured in direction, enables the Overcurrent Element when the above criteria is fulfilled (operation zone indicated in the diagram), while if configured in reverse direction, enables the Overcurrent Element when this criteria is not fulfilled (blocking zone indicated in the diagram).

All that stated for the **Zero Sequence Voltage Compensation Factor** is applicable to the **Sequence Voltage Compensation Factor**, if the negative sequence network is considered instead of the zero sequence network.

Figures 3.9.10 and 3.9.11 show the negative sequence network for a forward and reverse unbalanced fault (single phase or two phase), respectively.

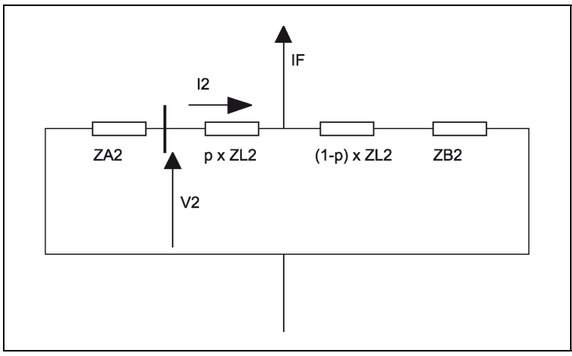

Figure 3.9.10 Negative Sequence Network for Forward Fault.

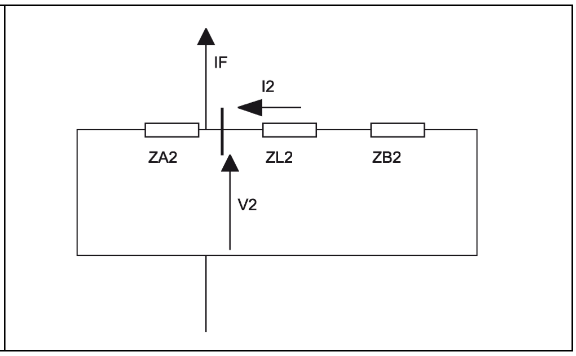

Figure 3.9.11 Negative Sequence Network for Reverse Fault.

If a forward fault, it can be deduced that $-V2 = ZA2 \cdot (-I2)$, where $ZA2$ is the negative sequence impedance of the local source. Consequently, it can be seen that the angle between $-V2$ and $I2$ will be that corresponding to this impedance. For this reason, this should be the characteristic angle of the directional negative sequence element (**ANG_67Q** setting).

The objective of the K_{COMP_67Q} factor is similar to that indicated for the K_{COMP_67N} factor in the Ground Directional Element:

- Increase the polarization phasor magnitude, in order that this exceeds the **Minimum Negative Sequence Voltage** setting.
- Compensate the inversion that the V2 voltage may undergo in lines with Series Compensation:

The logic diagram of operation of the Directional Negative Sequence Element is shown in Figure 3.9.12.

If the **Inversion of Directionality** (**IN_INV_TRIP D**) input is active, the direction of calculated direction is changed.

The activation of the **Ground Directional Element Inhibit** (**INH_DIR_NS**) input converts the element into non-directional.

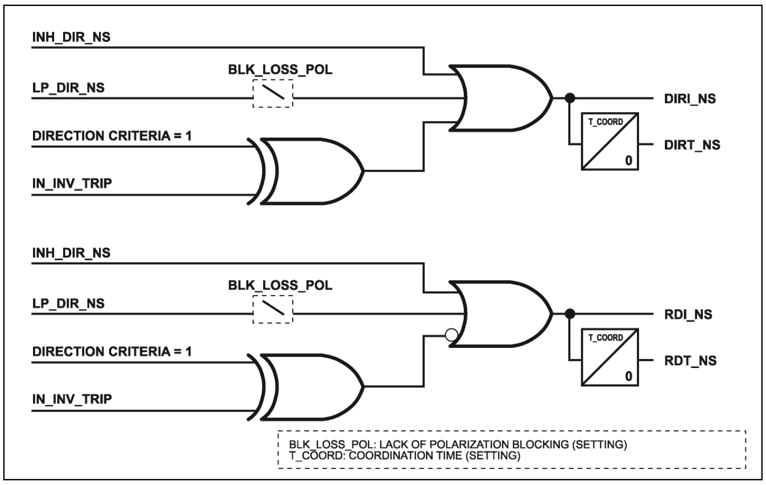

Figure 3.9.12 Block Diagram of a Directional Negative Sequence Element.

3.9.5 Directional Elements Settings

Directional Elements			
Setting	**Range**	**Step**	**By default**
Phase Characteristic Angle	0º - 90º	1º	45º
Zero Sequence Characteristic Angle	0º - 90º	1º	45º
Negative Sequence Characteristic Angle	0º - 90º	1º	45º
Lack of Polarization Blocking	YES / NO		NO
Minimum Phase Voltage	0.05 - 10 V	0.01 V	0.2 V
Minimum Zero Sequence Voltage	0.05 - 10 V	0.01 V	0.2 V
Minimum Negative Sequence Voltage	0.05 - 10 V	0.01 V	0.2 V
Coordination Time	0 - 30 ms	1 ms	0 ms
Zero Sequence Voltage Compensation Factor	0.00 - 50	0.01	0
Negative Sequence Voltage Compensation Factor	0.00 - 50	0.01	0

- **Directional Elements: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	**4 - OVERCURRENT**
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - LINE DIFFERENTIAL		**0 - PHASE CHARAC ANGLE**
1 - FUSE FAILURE		**1 - GND. CHARACT. ANGLE**
2 - DEAD LINE DETECTOR	**0 - DIRECTIONAL**	**2 - NEGSEQ CHARACT ANGLE**
3 - OPEN POLE LOGIC	1 - TIME OVERCURRENT	**3 - LACK POLARIZ BLOCK**
4 - OVERCURRENT	2 - INSTANTANEOUS	**4 - COORD. TIME**
...		**5 - MIN. PHASE VOLTAGE**
		6 - MIN. GND VOLTAGE
		7 - MIN. NEG SEQ VOLTAGE
		8 - RESID.VOLT. COMP.
		9 - NEGSEQ VOLT.COMP.

3.9.6 Digital Inputs and Events of the Directional Modules

Table 3.9-5: Digital Inputs and Events of the Directional Modules

Name	Description	Function
INH_DIR_PH	Directional Phase Element Inhibit	The activation of these inputs converts the directional elements into non-directional.
INH_DIR_N	Directional Ground Element Inhibit	
INH_DIR_SG	Directional Sensitive Ground Element Inhibit	
INH_DIR_NS	Directional Negative Sequence Element Inhibit	
INV_TRIP	Inversion of the Trip Direction	When the input is quiescent, the operation zones are those indicated in this section. If it is activated, the operation zone of all the directional elements is inverted.

3.9.7 Digital Outputs and Events of the Directional Modules

Table 3.9-6: Digital Outputs and Events of the Directional Modules

Name	Description	Function
RDI_A	Phase A Instantaneous Reverse Direction	Indication that the current flows in the direction opposite to that of the trip. The signals of time overcurrent elements are activated when the “coordination time” is up.
RDI_B	Phase B Instantaneous Reverse Direction	
RDI_C	Phase C Instantaneous Reverse Direction	
RDI_N	Ground Instantaneous Reverse Direction	
RDI_SG	Sensitive Ground Instantaneous Reverse Direction	
RDI_NS	Negative Sequence Inst. Reverse Direction	
RDT_A	Phase A Time Reverse Direction	
RDT_B	Phase B Time Reverse Direction	
RDT_C	Phase C Time Reverse Direction	
RDT_N	Ground Time Reverse Direction	
RDT_SG	Sensitive Ground Time Reverse Direction	
RDT_NS	Negative Sequence Time Reverse Direction	
DIRI_A	Phase A Instantaneous Direction	Indication that the current flows in the direction of the trip. The signals of time overcurrent elements are activated when the “coordination time” is up.
DIRI_B	Phase B Instantaneous Direction	
DIRI_C	Phase C Instantaneous Direction	
DIRI_N	Ground Instantaneous Direction	
DIRI_SG	Sensitive Ground Instantaneous Direction	
DIRI_NS	Negative Sequence Inst. Direction	
DIRT_A	Phase A Time Direction	
DIRT_B	Phase B Time Direction	
DIRT_C	Phase C Time Direction	
DIRT_N	Ground Time Direction	
DIRT_SG	Sensitive Ground Time Direction	
DIRT_NS	Negative Sequence Time Direction	

Table 3.9-6: Digital Outputs and Events of the Directional Modules		
Name	**Description**	**Function**
LP_DIR_PH_A	Lack Of Polarization for Phase A	Indication for loss of polarization from the corresponding directional unit.
LP_DIR_PH_B	Lack Of Polarization for Phase B	
LP_DIR_PH_C	Lack Of Polarization for Phase C	
LP_DIR_N	Lack Of Polarization for Ground	
LP_DIR_SG	Lack Of Polarization for Sensitive Ground	
LP_DIR_NS	Lack Of Polarization for Negative Sequence	
INH_DIR_PH	Directional Phase Element Inhibit	The same as for the digital inputs.
INH_DIR_N	Directional Ground Element Inhibit	
INH_DIR_SG	Directional Ground Element Inhibit	
INH_DIR_NS	Directional Negative Sequence Element Inhibit	
INV_TRIP	Inversion of the Trip Direction	The same as for the digital inputs.

3.9.8 Directional Elements Test

The enable **Pickup Blocking** or the **Torque Control** must be set to **Direction** and the inversion of directionality input must not be operational before running the test.

The test can be performed phase by phase: Ia with Vb, Ib with Vc, Ic with Va. Tables 3.9-7, 3.9-8, 3.9-9 and 3.9-10 present the angles between which the IED must enable direction. Whether or not the IED is seeing direction can be checked with the menu **Information** - **Status** - **Measuring Elements** - **Overcurrent** - **Directional Element** or in the ***ZIVercomPlus***® to **Status** - **Elements** - **Overcurrent** - **Directional** and the states of the flags of the phase being tested must be verified.

Table 3.9-7:Phase Directionality	
V APPLIED	I APPLIED
$Vb = 64V \angle 0^{o}$	$Ia = 1A \angle (\alpha$ phase char. -90^{o} to α phase char. $+90^{o}) \pm 2^{o}$
$Vc = 64V \angle 0^{o}$	$Ib = 1A \angle (\alpha$ phase char. -90^{o} to α phase char. $+ 90^{o}) \pm 2^{o}$
$Va = 64V \angle 0^{o}$	$Ic = 1A \angle (\alpha$ phase char. -90^{o} to α phase char. $+ 90^{o}) \pm 2^{o}$

Table 3.9-8: Directional Ground and Sensitive Ground by Vpol	
V APPLIED	I APPLIED
$Va = 64V \angle 180^{o}$	$In = 1A \angle (-(90^{o}+ \alpha$ ground char.) to $90^{o} - \alpha$ ground char.) $\pm 2^{o}$

Table 3.9-9: Directional Ground by Ipol	
I APPLIED	I APPLIED
$Ip = 1A \angle 180^{o}$	$In = 1A \angle (-90^{o}$ to $90^{o})$

Table 3.9-10: Negative Sequence Directionality	
V APPLIED	I APPLIED
$Va = 64V \angle 180^{o}$	$In = 1A \angle (-(90^{o}+ \alpha$ negative char.) to $90^{o} - \alpha$ negative char.) $\pm 2^{o}$

3.10 Protection Schemes for Overcurrent Elements

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3.10.1 Introduction

DLX-B terminal units include different Protection Schemes to complement the Instantaneous Directional Elements of Ground or Negative Sequence Overcurrent.

All schemes will use two elements, one **Underreach** and one **Overreach**. The first element will coincide with the Ground or Negative Sequence Instantaneous Overcurrent Element 1 (OR both). The Overreach Element will coincide. The Overreach Element will pickup when the logic input **Overreach Element Pickup** activates, to which the pickup signal of any Overcurrent Element could be assigned through the Programmable Logic.

Underreach and Overreach Elements must be forward looking. The Underreach Element must only operate with faults internal to the line, so that time delay must be zero, whereas the Overreach Element will also cover faults external to the line and must be time delayed.

The Underreach and Overreach instantaneous tripping may be performed as single-phase trip just by setting the value **Single-Phase Trip 67G** to **YES**.

The setting value for **Overcurrent Protection Schemes** may be configured as:

1. None.
2. Permissive Underreach Trip.
3. Direct Transfer Trip.
4. Permissive Overreach Trip.
5. Directional Comparison Unblocking.
6. Directional Comparison Blocking.

DLX-B IED comprises **Weak Infeed** logic and **Reverse Current Blocking** logic, which, if enabled, could supplement those Protection Schemes that so require.

3.10.2 Permissive Underreach Trip

Permissive Underreach is activated when selected in the **Overcurrent Protection Scheme** setting.

With this scheme, the pickup of the Underreach Unit at one of the line ends will generate an instantaneous trip and transmit this channel signal to the other end to allow tripping. The remote terminal will trip instantaneously when the channel signal is received if the Overreach Unit has picked up.

If weak or zero infeed conditions exist at one of the line ends and the Overreach Unit is not activated, this end could be tripped in an instantaneous mode, by means of **Weak Infeed Tripping Logic**, if the Underreach Unit has picked up at the "strong" end and has therefore sent a permissive tripping signal towards the "weak" end. To this end, **Overcurrent Weak Infeed Output** (**WI_OCM**) should be set to **Echo** + **Trip**, even if the echo signal is not used in the Permissive Underreach Scheme, it being considered useless.

If, because of weak or zero infeed conditions at one of the line ends, Underreach Unit does not pick up at no end, it is preferable to select a **Permissive Overreach** scheme together with the **Weak Infeed** logic.

3.10.2.a Channel Activation Conditions ("Overcurrent Channel Transmission")

The communications channel will be activated by any of the following conditions:

1. Pick up of the Underreach unit.
2. Pick up of the Overreach unit, provided the **Channel Reception** input is activated.
3. The three breaker poles tripped if **Open Breaker Transmission** is set to **YES**.

3.10.2.b Tripping Conditions ("Overcurrent Protection Scheme Trip")

The channel trip will take place upon channel reception and the pick up of the Overreach Unit or else signal **Overcurrent Weak Infeed Trip** is activated, (**TRIP_WI_OC**), for which **Overcurrent Weak Infeed Output** (**WI_OCM**) must be set to **Echo + Trip**.

3.10.2.c Operation

Channel activation and trip command generation are shown in the block diagram.

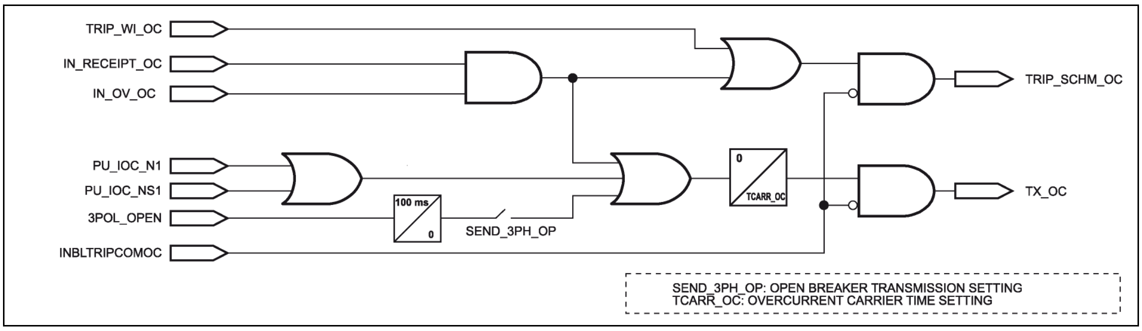

Figure 3.10.1 Permissive Underreach Scheme Block Diagram.

The purpose of **Overcurrent Carrier Time** (**TCARR_OC**) setting on the diagram is guaranteeing a minimum time for channel activation (**TX_OC**).

Open Breaker Transmission (**SEND_3PH_OP**) setting allows activating the channel upon the opening of the three breaker poles. The purpose of **T2** time delay of 100ms is delaying carrier transmission when this is produced by breaker trip.

Channel tripping and channel activation can be disabled using the status contact input **Overcurrent Channel Trip Blocking** (**INBLTRIPCOMOC**).

3.10.3 Direct Transfer Trip

Direct Transfer Trip Scheme is activated when selected in the **Overcurrent Protection Scheme** setting.

This scheme is similar to the **Permissive Underreach**, except that upon receiving the trip signal form the other end, a direct trip is generated with no additional monitoring.

3.10.3.a Channel Activation Conditions (“Overcurrent Channel Transmission”)

The communications channel will be activated by any of the following conditions:

1. Pick up of the Underreach unit.
2. The three breaker poles tripped if **Open Breaker Transmission** is set to **YES**.

3.10.3.b Tripping Conditions (“Overcurrent Protection Scheme Trip”)

Transfer Trip will always take place whenever channel reception takes place. For this to occur, the **Overcurrent Protection Scheme Trip** output must be connected, by means of the Programmable Logic, to the **Three-Phase Trip Enable** input.

3.10.3.c Operation

Channel activation and trip command generation are shown in the block diagram.

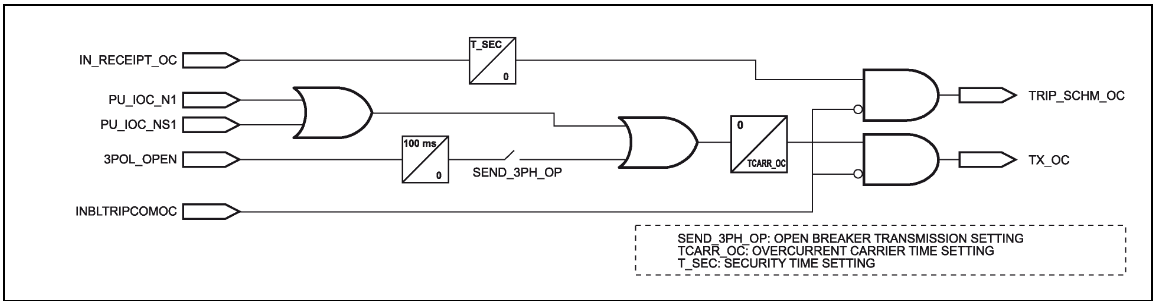

Figure 3.10.2 Direct Transfer Trip Scheme Block Diagram.

The purpose of **Overcurrent Carrier Time** (**TCARR_OC**) setting on the diagram is guaranteeing a minimum time for channel activation (**TX_OC**).

Open Breaker Transmission (**SEND_3PH_OP**) setting allows activating the channel upon the opening of the three breaker poles. The purpose of **T2** time delay of 100ms is delaying carrier transmission when this is produced by breaker trip.

The purpose of **Safety Time** (**T_SEC**) setting is guaranteeing a minimum duration of the received signal, thus avoiding undue operations upon channel noise.

Channel tripping and channel activation can be disabled using the status contact input **Overcurrent Channel Trip Blocking** (**INBLTRIPCOMOC**).

3.10.4 Permissive Overreach

Permissive Overreach is activated when selected in the **Overcurrent Protection Scheme** setting.

In this scheme, the pickup of the Overreach Unit at one of the line ends sends the permissive trip signal to the other end. The reception of the permissive signal produces an instantaneous trip if the Overreach Unit has pick up.

Overcurrent Reverse Current Blocking (**BLK_INV_A_OC**) signal, coming from **Reverse Current Logic** (for overcurrent), blocks, provided it is activated, the input coming from the Overreach Unit, to prevent wrong trips upon current reversal produced as a consequence of the sequential clearance of faults in a parallel line.

If weak or zero infeed conditions exist in one of the line ends, so that the Overreach Unit is not picked up, neither end may trip under this scheme (they will trip under time delayed conditions). In this case, the Permissive Overreach Scheme should be supplemented by the **Weak Infeed Logic**, which allows sending a trip permissive signal to the “strong” end (as an echo of the signal sent by said end) to achieve its tripping (**Overcurrent Weak Infeed Output** (**WI_OCM**) must be set to **Echo** or **Echo + Trip**), apart from giving the option for tripping the “weak” end (**Overcurrent Weak Infeed Output** (**WI_OCM**) must set to **Echo + Trip**).

3.10.4.a Channel Activation Conditions (“Overcurrent Channel Transmission”)

In order that the communication channel activation is produced at a terminal (permissive signal transmission), any of the following conditions must be met:

1. Pick up of the Underreach or Overreach unit.
2. The three breaker poles tripped if **Open Breaker Transmission** is set to **YES**.
3. **Overcurrent Echo** (**ECHO_OC**) activated, output of **Weak Infeed Logic**, for which **Overcurrent Weak Infeed Output** (**WI_OCM**) setting of said logic must be set to **Echo** or **Echo + Trip**.

3.10.4.b Tripping Conditions (“Overcurrent Protection Scheme Trip”)

Channel trip will take place upon channel reception and pickup of the Overreach Unit or if **Overcurrent Weak Infeed Trip** (**TRIP_WI_OC**) is activated, for which **Overcurrent Weak Infeed Output** (**WI_OCM**) of the **Weak Infeed Logic** (for Overcurrent Elements) must be set to **Echo + Trip**.

3.10.4.c Operation

Channel activation and generation of a trip command are shown in the following block diagram:

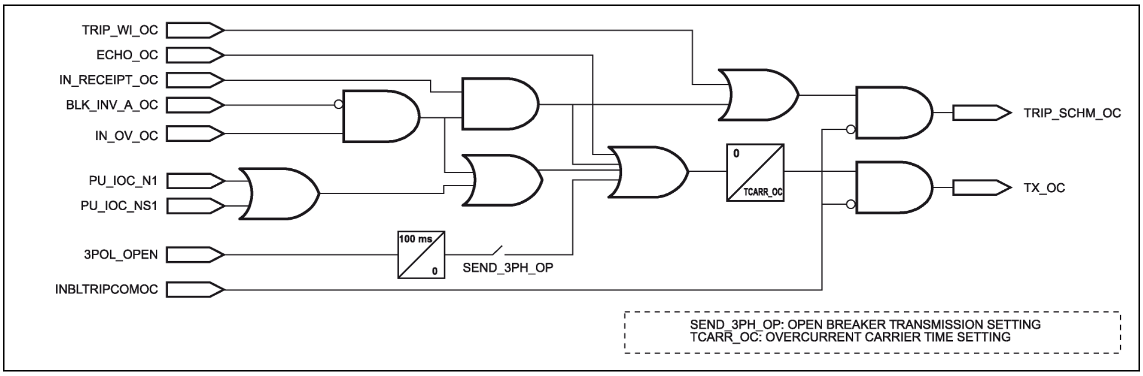

Figure 3.10.3 Permissive Overreach Scheme Block Diagram.

The purpose of **Overcurrent Carrier Time** (**TCARR_OC**) setting on the diagram is guaranteeing a minimum time for channel activation (**TX_OC**).

Open Breaker Transmission (**SEND_3PH_OP**) setting allows channel activation when all three breaker poles have tripped. The purpose of **T2** timing of 100 ms is to delay carrier transmission when it is produced by breaker tripping.

Channel tripping and channel activation can be disabled using the status contact input **Overcurrent Channel Trip Blocking** (**INBLTRIPCOMOC**).

3.10.5 Directional Comparison Unblocking

Directional Comparison Unblocking is activated when selected in the **Overcurrent Protection Scheme** setting.

In Permissive schemes using carrier wave channels, the trip permissive signal is frequently transmitted through the faulted phase/s, and the signal is attenuated, in a number of cases, to such a low level that the signal does not reach the other end. The end not receiving the trip permissive signal will not be able to trip following the Permissive Overreach Scheme (it will produce time delayed trip). In order to avoid timed trips upon this type of situations, the **Directional Comparison Unblocking** Scheme is used, which is an extension of the **Permissive Overreach** Tripping Scheme.

The **Directional Comparison Unblocking** Scheme has been introduced to be used with switched frequency carrier wave equipment. When no fault is present in the line, this equipment continuously sends a signal at a “guard” frequency (guard signal) for channel supervision. Upon detecting a fault, the relay commands the carrier wave equipment to switch the guard frequency to other frequency known as “trip frequency” (trip signal). Thus, but for the time elapsed in the switching process, the teleprotection equipment will never send both signals at the same time.

Upon receipt of the trip signal and non-receipt of the guard signal at one end, said end will trip following the same criteria set up in a **Permissive Overreach** Scheme (provided the Overreach Unit is picked up). On the contrary, upon non-receipt of the trip signal and non-receipt of the guard signal, the **Directional Comparison Unblocking** Scheme will allow, during a time window, the instantaneous tripping of the overreaching unit.

Overcurrent Reverse Current Blocking (**BLK_INV_A_OC**) signal coming from the **Reverse Current Blocking Logic** (associated to overcurrent schemes), blocks, while activated, the input coming from the pickup of the overreaching unit, with the purpose of preventing wrong trips upon current reversals as a consequence of clearing faults in a parallel line in case of double circuits.

The same as for the **Permissive Overreach** Scheme, if weak or zero infeed conditions exist at one of the line ends, so that the overreaching unit of said end does not pick up, none of the ends can trip with this scheme (it would produce time delayed trip). In this case, the **Directional Comparison Unblocking** Scheme should be supplemented by the **Weak Infeed Logic**, which allows the transmission of a trip permissive signal to the “strong” end (as echo of the signal transmitted by said end) in order to achieve its trip (**Overcurrent Weak Infeed Output** (**WI_OCM**) must be set to **Echo** or **Echo + Trip**), apart from giving the option to trip the “weak” end (**Overcurrent Weak Infeed Output** (**WI_OCM**) must be set to **Echo + Trip**).

3.10.5.a Channel Activation Conditions (“Overcurrent Channel Transmission”)

For communication channel activation at a terminal (transmission of the permissive signal), any of the following conditions must be present:

1. Pick up of the Underreach or Overreach unit.
2. The three breaker poles tripped if **Open Breaker Transmission** is set to **YES**.
3. Activation of **Overcurrent Echo** (**ECHO_OC**) signal, **Weak Infeed Logic** output, for which **Overcurrent Weak Infeed Output** (**WI_OCM**) of said logic must be set to **Echo** or **Echo + Trip**.

3.10.5.b Tripping Conditions (“Overcurrent Protection Scheme Trip”)

Tripping by channel signal reception will occur under the following conditions:

1. Channel reception and loss of guard and Overreach Unit picked up.
2. Loss of guard, without channel activation, and Overreach Unit picked up before **T_TRIP** times out.
3. **Overcurrent Weak Infeed Trip** (**TRIP_WI_OC**) activated, for which **Overcurrent Weak Infeed Output** (**WI_OCM**) of **Weak Infeed Logic** (for Overcurrent elements) must be set to **Echo + Trip**.

3.10.5.c Operation

Activation of a channel and generation of a trip command are shown in the following block diagram:

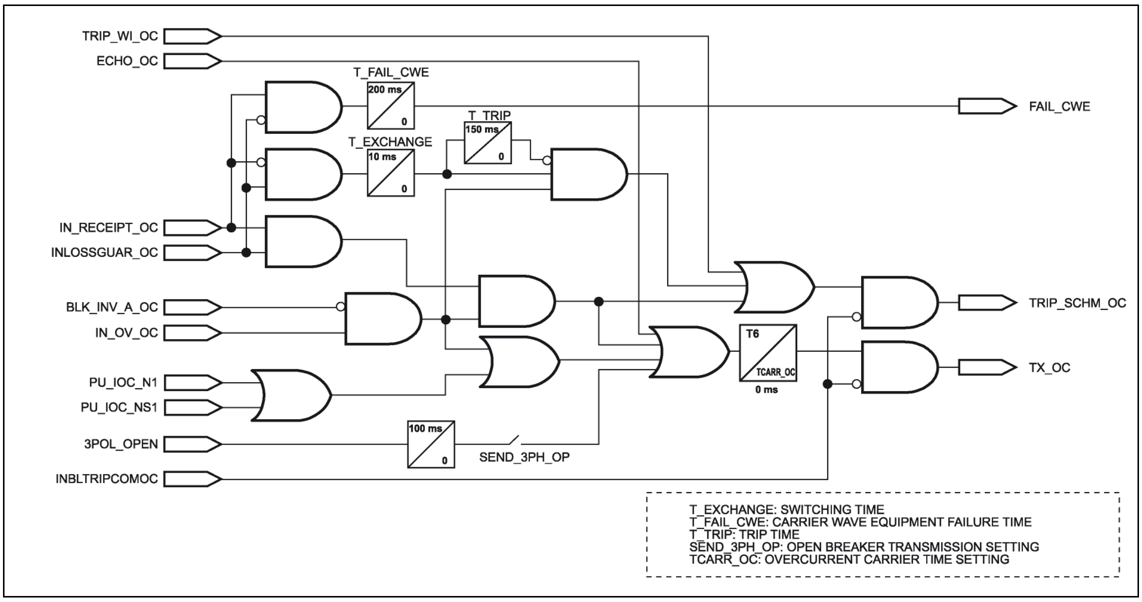

Figure 3.10.4 Directional Comparison Unblocking Scheme Block Diagram.

The purpose of **Overcurrent Carrier Time** (**TCARR_OC**) on the diagram is guaranteeing a minimum time for channel activation (**TX_OC**).

The purpose of **Open Breaker Transmission** (**SEND_3PH_OP**) setting is activating the channel when the three breaker poles trip. The purpose of **T2** timing of 100 ms is delaying the carrier transmission caused by breaker tripping.

The carrier wave equipment features the following output contacts: one normally closed (hereafter called **Guard**), which remains open when the guard signal is being received, and other normally open (hereafter called **Trip**) which closes upon the reception of the trip signal from the other end. The guard contact must be wired to the **DLX Overcurrent Guard Loss** input - **INLOSSGUAR_OC**-, whereas the contact trip will be wired to the **IN_RECEIPT_OC** (**Overcurrent Channel Reception**) input. On the other hand the **TX_OC** (**Overcurrent Channel Activation**) output (**DLX** IED output) must be wired to the wave carrier equipment input, which will give the command for frequency switching.

When both **INLOSSGUAR_OC** and **IN_RECEIPT_OC** inputs are activated, the response is exactly equal to a Permissive Overreach Scheme, an instantaneous tripping being produced provided the overreaching unit is picked up.

In case only **INLOSSGUAR_OC** input is activated, which might indicate a complete attenuation of the trip permissive signal from the other end, if this situation remains during the switching time **T_EXCHANGE**=10 ms (enough for the carrier wave equipment to switch from guard frequency to trip frequency), the overreaching unit will be allowed to trip instantaneously during the time **T_TRIP**=150 ms.

If only **IN_RECEIPT_OC** input has been activated, after time **T_FAIL_CWE**, the signal **FAIL_CWE**=200 ms will be activated, which indicates failure in the carrier wave equipment.

Channel tripping and channel activation can be disabled using the status contact input **Overcurrent Channel Trip Blocking** (**INBLTRIPCOMOC**).

3.10.6 Directional Comparison Blocking

Directional Comparison Blocking is activated when selected in the **Overcurrent Protection Scheme** setting.

The main difference between this scheme and the others is that the channel signal is transmitted to avoid remote tripping instead of accelerating it.

Proper operation of this scheme requires that the Ground or Negative Sequence Element, used to activate the channel, be selected as reverse looking. The reverse looking element will pickup when the logic input **Reverse Direction element** activates, to which the pickup signal of any Overcurrent Element could be assigned

The pickup of the reverse direction unit at a line end will send the trip blocking signal to the remote-end to avoid tripping by Overreach Unit. This way, the trip is only produced upon non-receipt of the blocking signal from the remote end terminal of the line.

Correct application of this scheme requires that the following conditions be satisfied:

1. The pick up setting of the reverse direction unit must be lower than the setting of the overreaching unit in the rest of terminals, so as to guaranteeing the blocking of any external fault outside the line for which the overreaching unit/s picked up.
2. An overreaching unit trip delay time must be considered to allow the communication equipment to transmit the blocking signal from the remote to the local terminal. Said delay is given by **Overcurrent Delay Time** setting.

Echo and **Weak Infeed Trip Logic** are purposeless under this scheme. On the other hand, this scheme needs not be supplemented by the **Reverse Current Blocking Logic** because this scheme can detect the current reversal thanks to the use of the reverse direction unit.

3.10.6.a Channel Activation Conditions ("Overcurrent Channel Transmission")

The communications channel (trip blocking) will activate under the following condition:

1. Pickup of the reverse direction unit, with no activation of the overreaching unit and non-existence of any conditions for transmission disable.
2. Channel trip blocking input activated and non-existence of any conditions for transmission disable. In this case, as it is a blocking system, channel activation means trip blocking.

3.10.6.b Channel Stop Conditions ("Overcurrent Channel Disable")

The communications channel (trip blocking) will deactivate (trip blocking signal deactivated) under any of the following conditions:

1. Activation of the **Channel Stop** status contact input.
2. Overreach unit activation without channel signal reception, reverse direction activation or activation of the **Channel Tripping Blocking** input.
3. Underreach Unit activation.

3.10.6.c Tripping Conditions ("Overcurrent Protection Scheme Trip")

A trip using this protection scheme will occur provided the following conditions are satisfied at the same time:

1. Overreach Unit activation.
2. No channel signal is received (blocking signal, from the other terminal).
3. Reverse direction unit is not activated.

3.10.6.d Operation

Activation of a channel and generation of a trip command are shown in the following block diagram:

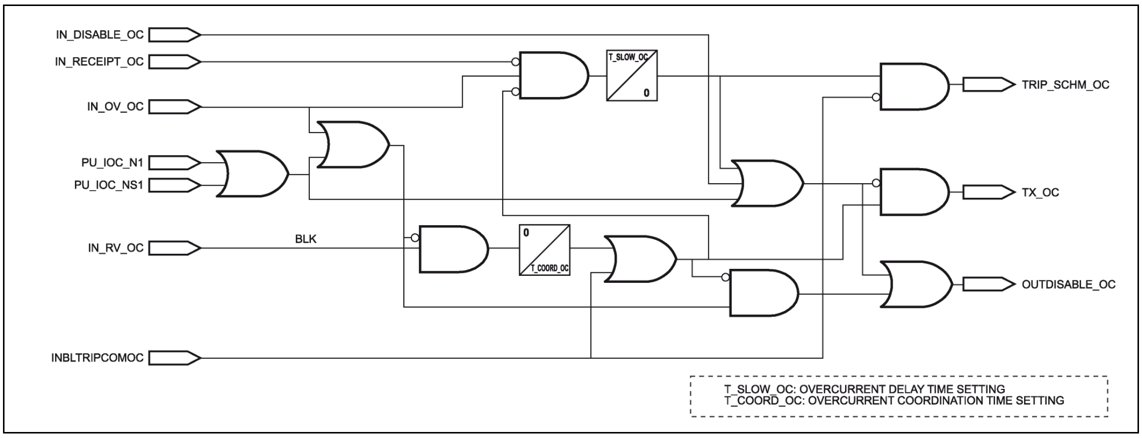

Figure 3.10.5 Directional Comparison Blocking Scheme Block Diagram.

The purpose of **Overcurrent Delay Time** (**T_SLOW_OC**) setting, as previously mentioned, is to allow, for external faults, a time lapse for the receipt of the blocking signal from the remote end terminal.

Overcurrent Coordination Time (**T_COORD_OC**) sets a reset time for the reverse direction unit pickup signal, so as to prevent channel disable upon current reversal in double circuits, as a consequence of sequential parallel line breaker trips on a fault in the same. It is worth mentioning that the Underreach Unit may disable the blocking transmission, no matter the pickup of the reverse direction unit, as said Underreach Unit is only picked up upon internal line faults.

The purpose of **DLX Channel Disable** output is to be wired to the teleprotection equipment **PARADA_CANAL** input so as to disable the channel. However, said output also disables the channel activation output as a prevention measure, in case **PARADA_CANAL** input has not been setup in the teleprotection equipment as a priority against **ACTIVACION_CANAL** input, when both are active.

Channel tripping and channel activation can be disabled using the status contact input **Overcurrent Channel Trip Blocking** (**INBLTRIPCOMOC**).

3.10.7 Weak Infeed Logic

The **Weak Infeed Logic**, if enable, can work in parallel with all permissive teleprotection schemes.

As mentioned before, if a permissive overreaching scheme has been selected (or Directional Comparison Unblocking) and one of the line ends is in a weak infeed condition, so that overreaching unit is not picked up at said end, none of the line terminals can trip instantaneously. To this end, the teleprotection scheme must be supplemented by the **Weak Infeed Logic**, which presents two options: **Echo Transmission** and **Weak Infeed Tripping**.

3.10.7.a Echo Logic

This function is enabled by setting **Overcurrent Weak Infeed Output** (**WI_OCM**) to **Echo**.

The Echo function allows sending a permissive trip signal to the “strong” end (as echo of the signal transmitted by said end).

The Echo signal will be activated provided a signal from the other end has been received and the reverse direction unit has not picked up.

3.10.7.b Weak Infeed Tripping

This function is enabled by setting **Overcurrent Weak Infeed Output** (**WI_OCM**) to **Echo + Trip**.

The echo transmission allows the trip (instantaneous) of the “strong” end, but not the “weak” end trip. The Weak Infeed trip allows tripping this latter end when undervoltage conditions are detected, a permissive trip signal has been received and the reverse direction unit or the overreaching unit is not picked up.

3.10.7.c Operation

Figure 3.10.6 shows the logic operating diagram.

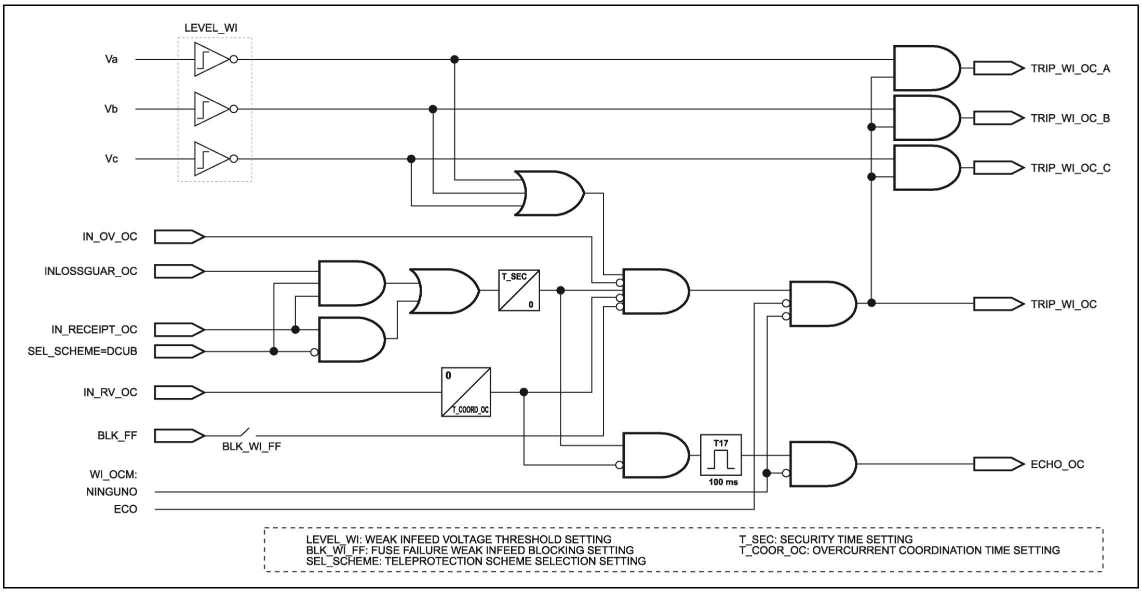

Figure 3.10.6 Weak Infeed Logic Block Diagram.

Undervoltage detectors (represented as negated overvoltage detectors) pickup and reset with only one value, equal to **Weak Infeed Voltage Threshold** (**LEVEL_WI**) setting.

The purpose of **Safety Time** (**T_SEC**) setting is guaranteeing a channel receipt time to avoid echo transmission upon channel noise.

If a **Directional Comparison Unblocking** scheme has been selected, the **Channel Receipt** (**IN_RECEIPT_OC**) must be supplemented with **Guard Loss** (**INLOSSGUAR_OC**) input activation.

The setting **Overcurrent Coordination Time** (**T_COORD_OC**) is used to prevent weak infeed trips upon current reversal in double circuits.

The Weak Infeed trip can be blocked by **Fuse Failure Blocking** (**BLK_FF**) signal activation, provided **Fuse Failure Weak Infeed Blocking** (**BLK_WI_FF**) is set to **YES**, as the indication of undervoltage detectors is not reliable upon a fuse failure.

TRIP_WI_I_A, **TRIP_WI_I_B** and **TRIP_WI_I_C** outputs act as phase selectors (as will be seen in Single-Phase / Three-Phase Trip Logic) when the setting **67G Single-Phase Trip** is set to **YES**, as under weak infeed conditions the phase selector may generate no outputs, the positive sequence current being very small.

3.10.8 Transient Blocking by Current Reversal Logic

In double circuits, the sequential trips of the breakers associated to one of the lines, as a consequence of the clearance of a fault in the same, can produce a current reversal in the parallel line. Said current reversal will cause the activation of the overreaching unit hitherto deactivated at one end and the reset of said unit at the opposite end. As these events do not occur at the same time, overreaching teleprotection schemes can give way to wrong trips in the unimpaired line.

Figure 3.10.7 represents a current reversal event.

In case of a Permissive Overreach Scheme, a current reversal in line 2 takes place upon the trip of the breaker in B1, and the B2 relay overreaching unit picks up. If the trip permissive signal coming from the relay in A2 has not yet reset a channel trip will be produced in B2. In order to avoid these types of wrong trips the B2 relay overreaching unit should be temporarily blocked.

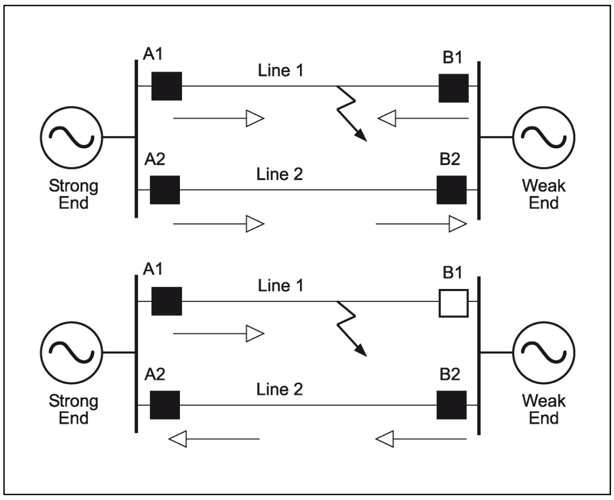

Figure 3.10.7 Current Reversal Event.

3.10.8.a Operation

The **Transient Blocking by Current Reversal Logic** generates **Overcurrent Reverse Current Blocking** (**BLK_INV_A_OC**) signal when the reverse direction unit picks up. Said signal **BLK_INV_A_OC** will stay active during **Overcurrent Coordination Time** (**T_COORD_OC**) setting, from the reset of the reverse direction unit.

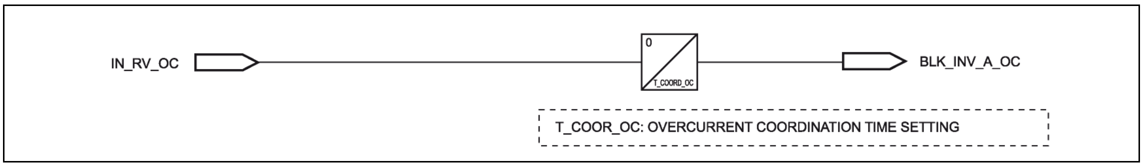

Figure 3.10.8 Block Diagram for Reverse Current Blocking Logic (Overcurrent).

3.10.9 Programmable Schemes

Apart from the available protection schemes, any other protection scheme can be setup by means of the programmable logic incorporated into the equipment. In this case, teleprotection schemes can be generated, which need the transmission of several signals between both line ends (indication of the faulted phase, single-phase and three-phase permissive signals, etc), for which a digital network may be the communication media.

3.10.10 Overcurrent Elements Protection Schemes Settings

Overcurrent Protection Schemes			
Setting	**Range**	**Step**	**By default**
Carrier Transmission Enable by 52 Open	YES / NO		YES
Carrier Reception Safety Time	0 - 50 ms	1 ms	0 ms
Weak Infeed Voltage Level	15.00 - 70.00 V	0.01 V	45 V
Weak Infeed Trip Blocking due to Fuse Failure	YES / NO		NO
Protection Scheme	None Permissive Underreach. Direct Transfer Trip. Permissive Overreach. Directional Comparison Unblocking. Directional Comparison Blocking.		None
Carrier Time	0 - 200 ms	10 ms	50 ms
Coordination Time (Reverse Current Blocking Logic)	0 - 50 ms	1 ms	25 ms
Overreaching Unit in Blocking Schemes Time Delay	0 - 200 ms	10 ms	50 ms
Weak Infeed Logic Output	NONE ECHO ECHO + TRIP		None
Reverse Current Blocking Logic	YES / NO		NO

- **Overcurrent Elements Protection Schemes: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	4 - OVERCURRENT
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - LINE DIFFERENTIAL	**0 - CARRIER BY OPEN BRKR**
1 - FUSE FAILURE	**1 - SECURITY TIME**
2 - DEAD LINE DETECTOR	**2 - WI UNDERVOLT LEVEL**
...	**3 - FF WI BLOCK**
12 - PROTECTION SCHEME	**4 - O/C PROTEC SCHEME**
...	

0 - LINE DIFFERENTIAL	0 - CARRIER BY OPEN BRKR	**0 - O/C PROTEC SCHEME**
1 - FUSE FAILURE	1 - SECURITY TIME	**1 - O/C CARRIER TIME**
2 - DEAD LINE DETECTOR	2 - WI UNDERVOLT LEVEL	**2 - O/C COORD TIME**
...	3 - FF WI BLOCK	**3 - O/C DELAY DCB**
12 - PROTECTION SCHEME	**4 - O/C PROTEC SCHEME**	**4 - O/C WI LOGIC OUTPUT**
...		**5 - O/C CUR INV BLOCK**

3.10.11 Digital Inputs and Events of the Overcurrent Protection Schemes Module

Table 3.10-1: Digital Inputs and Events of the Overcurrent Protection Schemes Module

Name	Description	Function
IN_RECEIPT_OC	Overcurrent Channel Receipt Input	The activation of this input means a signal receipt (trip permissive or blocking, as a function of the selected scheme) from the other end.
INBLTRIPCOMOC	Overcurrent Channel Trip Blocking Input	The activation of this input blocks the trip of any overcurrent protection scheme.
INLOSSGUAR_OC	Overcurrent Guard Signal Loss Input	The activation of this input means that the guard signal receipt has ceased. It is used in the Directional Comparison Unblocking scheme.
IN_DISABLE_OC	Overcurrent Channel Disable Input	The activation of this input generates Channel Disable output. It is used in the Directional Comparison Blocking scheme.
IN_OV_OC	Overreach Element Pickup Input	Overreach overcurrent element pickup
IN_RV_OC	Reverse Looking Element Pickup Input	Reverse looking overcurrent element pickup

3.10.12 Digital Outputs and Events of the Overcurrent Protection Schemes Module

Table 3.10-2: Digital Outputs and Events of the Overcurrent Protection Schemes Module

Name	Description	Function
TRIP_SCHM_OC	Overcurrent Protection Scheme Trip	Selected overcurrent protection scheme trip.
TX_OC	Overcurrent Channel Transmission	Channel activation by the selected overcurrent protection scheme.
FAIL_CWE	Carrier Wave Equipment Failure	Carrier wave equipment failure.
OUTDISABLE_OC	Overcurrent Channel Disable	Output for channel disabling used in Directional Comparison Blocking scheme.
TRIP_WI_OC	Overcurrent Weak Infeed Trip	Weak infeed condition trip in overcurrent protection scheme.
TRIP_WI_OC_A	Phase A Overcurrent Weak Infeed Trip	Trip by weak infeed condition in phase A in overcurrent protection scheme.
TRIP_WI_OC_B	Phase B Overcurrent Weak Infeed Trip	Trip by weak infeed condition in phase B in overcurrent protection scheme.
TRIP_WI_OC_C	Phase C Overcurrent Weak Infeed Trip	Trip by weak infeed condition in phase C in overcurrent protection scheme.
ECHO_OC	Overcurrent Echo Transmission	Echo transmission in overcurrent protection scheme.
BLK_INV_A_OC	Overcurrent Reverse Current Blocking	Overreaching unit blocking in overcurrent protection scheme by current reversal detection.
IN_RECEIPT_OC	Overcurrent Channel Receipt Input	The same as for the Digital Input.
INBLTRIPCOMOC	Overcurrent Channel Trip Blocking Input	The same as for the Digital Input.
INLOSSGUAR_OC	Overcurrent Guard Signal Loss Input	The same as for the Digital Input.
IN_DISABLE_OC	Overcurrent Channel Disable Input	The same as for the Digital Input.
IN_OV_OC	Overreach Element Pickup Input	Overreach overcurrent element pickup.
IN_RV_OC	Reverse Looking Element Pickup Input	Reverse looking overcurrent element pickup.

3.11 Open Phase Unit

3.11.1 Operating Principles 3.11-2
3.11.2 Open Phase Unit Settings 3.11-4
3.11.3 Digital Inputs and Events of the Open Phase Module 3.11-6
3.11.4 Digital Outputs and Events of the Open Phase Module 3.11-6
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3.11.1 Operating Principles

The Open Phase Unit is for the purpose of detecting series faults, which may occur due to the rupture of an overhead line conductor. A series fault generates an unbalanced condition which can be detected by measuring the negative sequence current (I2). The Overcurrent Units incorporated in the **DLX** which use this magnitude should present pick up levels above the maximum unbalance which may arise in the line under normal conditions (without fault). This unbalance will be greater the more unbalanced the line, such that, in a maximum load condition, the negative sequence current may come to be in the neighborhood of that corresponding to a series fault. This would impede the Negative Sequence Overcurrent Units from detecting this type of fault. The open-phase unit uses the negative sequence (I2) as well as the positive sequence (I1) current and operates based on the (I2/I1) ratio, thus making its operation independent from the line load.

The pickup of the unit occurs when this ratio exceeds the setting startup value. Figures 3.11.1, 3.11.2 and 3.11.3 represent the block diagram of this unit.

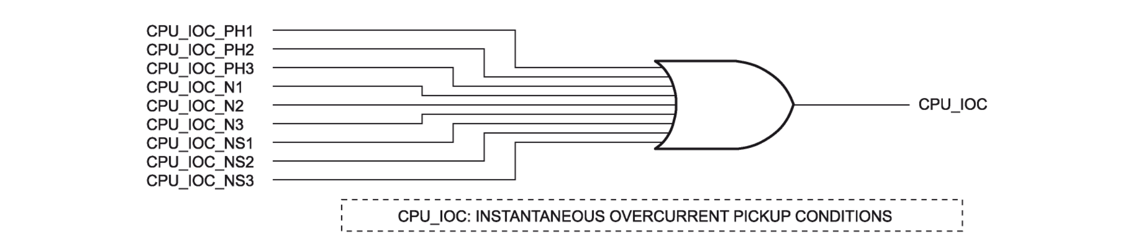

Figure 3.11.1 Activation Logic of the Pick Up Condition Signal of the Instantaneous Overcurrent Elements used by the Open Phase.

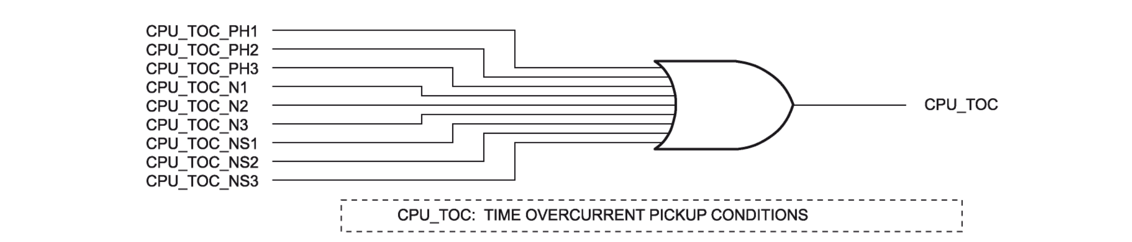

Figure 3.11.2 Activation Logic of the Pick Up Condition Signal of the Time Overcurrent Elements used by the Open Phase.

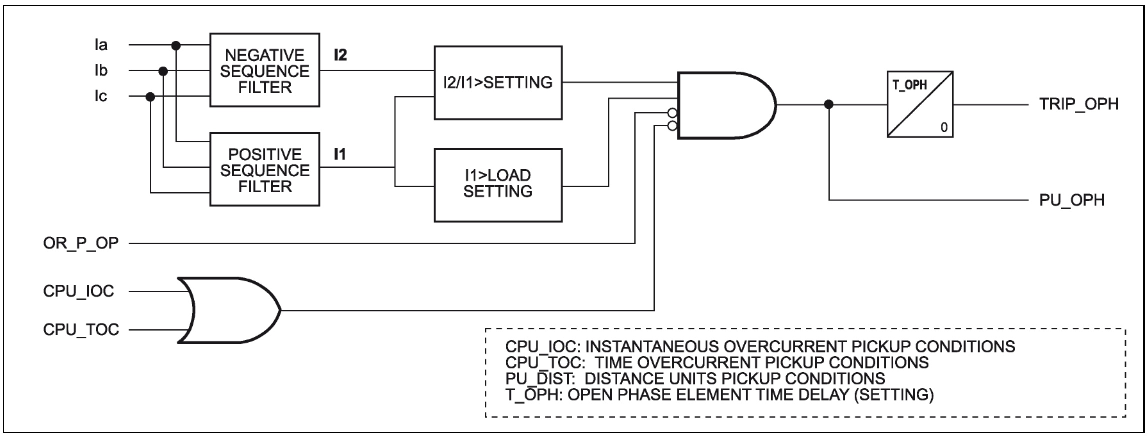

Figure 3.11.3 Block Diagram of the Open-Phase Unit.

Once picked up, the element acts if the pickup is maintained for a period of time equal to or greater than the set value.

The operation of this function is conditioned to the position of the breaker and to the level of the positive sequence current: if any breaker pole (**OR_P_OP**) is open or the positive sequence current is less than the **Positive Sequence Sensitivity** setting, the unit will be disabled. Similarly, the function will be cancelled when there is a pickup of any of the Distance Elements or a pick up condition (without considering the directionality) of any of the Overcurrent Elements: phase, ground or sequence time or instantaneous. In this manner, the actuation of the open phase unit is only ensured in case of series faults.

When the aperture of a single pole of the breaker is produced (single-phase or transient reclose sequence in a three-phase trip in which the three poles do not open at the same time), an unbalanced condition similar to that of a series fault will be originated. The **Any Pole Open** (**OR_P_OP**) signal allows detecting the previous condition and blocks the open phase unit. Notwithstanding, the relay will always measure a negative sequence current before activating the **OR_P_OP** signal. This measured current may cause the open phase unit to pick up before it receives the blocking signal, for which it is necessary to establish a minimum timing.

Pick up occurs when the value measured exceeds 1.02 times the pickup setting and resets at 0.97 times the pickup setting.

3.11.2 Open Phase Unit Settings

Open Phase Unit			
Setting	**Range**	**Step**	**By default**
Enable	YES / NO		NO
Pickup I2 = negative sequence current I1 = positive sequence current	0.05 - 0.4 I2/I1	0.01	0.05
Minimum Load	(0.02 - 1) In	0.01 A	0.1 In
Time Delay	0.05 - 300 s	0.01 s	0.05

- **Open Phase Unit: HMI Access (DLX-A Model)**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - OPEN POLE LOGIC
2 - ACTIVATE GROUP	2 - RECLOSER	2 - OVERCURRENT
3 - CHANGE SETTINGS	3 - LOGIC	**3 - OPEN PHASE DETECTOR**
4 - INFORMATION	...	4 - CT SUPERVISION
		5 - THERMAL IMAGE
		6 - COLD LOAD
		7 - BREAKER FAILURE
		8 - POLE DISCREPANCY
		9 - PHASE SELECTOR
		10 - PROTECTION LOGIC

0 - LINE DIFFERENTIAL	**0 - OPEN PHASE ENABLE**
1 - OPEN POLE LOGIC	**1 - OPEN PHASE PU**
2 - OVERCURRENT	**2 - OPEN PHASE WAIT TIME**
3 - OPEN PHASE DETECTOR	**3 - MIN. LOAD OPEN PHASE**
4 - CT SUPERVISION	
...	

- **Open Phase Unit: HMI Access (DLX-B Model)**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	4 - OVERCURRENT
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - LINE DIFFERENTIAL	
1 - FUSE FAILURE	**0 - OPEN PHASE ENABLE**
2 - DEAD LINE DETECTOR	**1 - OPEN PHASE PU**
...	**2 - OPEN PHASE WAIT TIME**
7 - OPEN PHASE DETECTOR	**3 - MIN. LOAD OPEN PHASE**
...	

3.11.3 Digital Inputs and Events of the Open Phase Module

Table 3.11-1: Digital Inputs and Events of the Open Phase Module		
Name	**Description**	**Function**
ENBL_OPH	Open Phase Detector Enable Input	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a "1."

3.11.4 Digital Outputs and Events of the Open Phase Module

Table 3.11-2: Digital Outputs and Events of the Open Phase Module		
Name	**Description**	**Function**
PU_OPH	Open Phase Detector Pickup	Pickup of the time count element.
TRIP_OPH	Open Phase Detector Trip	Trip of the element.
OPH_ENBLD	Open Phase Detector Element Enabled	Indication of enabled or disabled status of the detector.
ENBL_OPH	Open Phase Detector Enable Input	The same as for the Digital Input.

3.11.5 Open Phase Element Test

After putting all the phase and ground units out of service, this two-current system is applied:

Ia = 1/0º and Ib = 1/60º (it is understood that these angles are inductive).

After setting the element to 0.2 I2/I1, it must not be picked up. After increasing the phase B current, the element must pick up (the pickup flag at "1") with a current value in phase B between 1.493 Aac and 1.348 Aac.

With the trip time set to 10 s, a current of 2 A / 60º is applied in phase B. A trip must be initiated between 10.1 s and 9.9 s. Also the trip contacts must close.

In model **DLX**, the unit is set to 0.2 I1/I1.2 and the **Minimum Load** in the line to 1.2 A. Applying Ia = 1/0º and Ib = 2/60º, the unit should not operate. If, under the same conditions, the **Minimum Load** in the line is set to 0.8 A, the unit should pick up.

3.12 Thermal Image Unit

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3.12.1 Operating Principles

Thermal relays, which directly measure the temperatures of the machine to be protected, have very serious problems in accomplishing their function in more sensitive areas (windings), having to take measurements in nearby areas (oil, insulators, etc.). This indirect measurement involves drawbacks because the points where the direct temperature measurements are made belong to elements with significant thermal inertia. Therefore, indirect measurement requires the use of thermal units with algorithms that require experimental studies of the element to be protected, which generally are unavailable.

For this reason, instead of using thermal relays, thermal image protections are commonly used. Using mathematical algorithms based on the material's physics, they estimate the temperature of the machine to be protected using the currents that flow through the machine.

It is assumed that when machine overloads occur, the main cause for deterioration is the thermal phenomenon; possible dynamic effects are not considered.

DLX protection terminals have a Thermal Image Protection Unit that estimates the thermal state by measuring the current flow and resolving the thermal differential equation in order to generate a trip when high temperature levels are reached.

The algorithms are based on modeling the heating of a resistive element when running an electric current through it. The effect of radiation is not considered (since the impact is considered negligible given the temperatures reached by the elements to be protected, less than 400 ºC), nor are heat dissipation sources other than that deriving from the Joule effect.

Cooling of the equipment is also simulated if the current value returns to the rated range after a relatively short overload period.

The Thermal Image Unit does not have a threshold at which pickup starts: it is always "picked up". The trip time depends on the current flowing from a given instant up to when the temperature limit is reached and the temperature value at a specific instant. The prior temperature depends on what has happened before, the measured current and the time applied.

The differential equation that controls any thermal phenomenon is the following:

$$I^2 = \theta + \tau \cdot \frac{d\theta}{dt}$$

Where:

- I: Is the RMS value of the measured current.
- τ: Is the time constant. Adjustable parameter.
- Imax: Value of the maximum admissible sustained current. Adjustable parameter.

The time constant is represented by τ and it represents the time needed for a body that will go from an initial temperature θ_0 to a final temperature θ_∞ to reach 63% of the temperature increase necessary for θ_∞; that is, the time it will take to reach the intermediate temperature θ_i starting from θ_0, where:

$\theta_i = \theta_0 + (\theta_\infty - \theta_0) * 0.63$

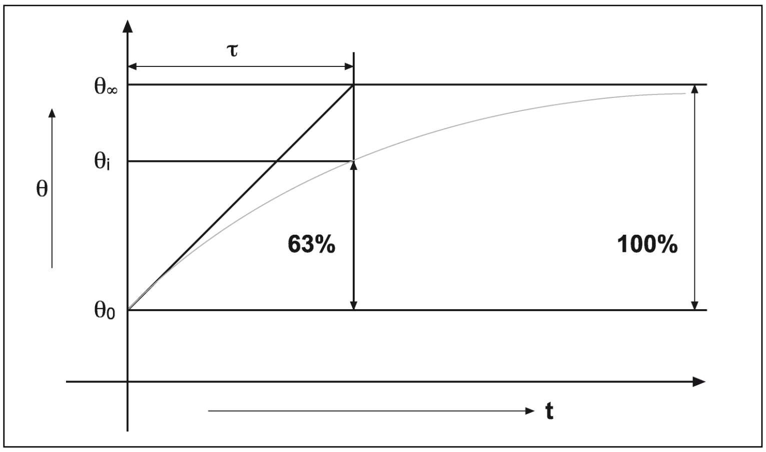

Figure 3.12.1 Time Constant (Thermal Image).

Temperature values (θ) are always stored in case there is a failure in the IED's power supply. There is a **Thermal Memory** setting that you can set to YES so that the initial temperature value will be the stored one whenever the IED is reinitialized.

This unit is prepared to protect lines, motors and transformers from overheating. A setting is selected to indicate which of these types are to be protected.

For lines, the measuring current used is the sum of the square of phase A. It has two time constants, one for heating (while there is current) and one for cooling (when the positive sequence current is under 0.1 amperes).

For motors, the measuring current used is the sum of the square of the positive sequence and the square of the negative sequence. This last value is multiplied by a scaling factor. It has two time constants, one for motor stopped (when the positive sequence is under 0.15 times the maximum current) and another for motor running (when the positive sequence is above 0.30 times the maximum current).

For transformers, the measuring current used is the square of the current flowing through a winding determined by setting. It has two time constants, one for being ventilated and the other for not being ventilated. A digital input changes from one to the other. The default time constant is "with ventilation." To change it, the change-of-constant input must be configured. Activating this input changes the constant to "without ventilation."

The Thermal Image Unit estimates the thermal state in each case (line/motor/transformer) and, when it reaches the level equivalent to that obtained by the constant flow of Imax, it provides a trip output.

In addition to the trip level, the unit has an adjustable alarm level.

The thermal state is estimated thus:

- The initial value is $\theta = 0$ or $\theta \neq 0$, depending on the initial thermal state.
- The thermal image unit is activated every 500 milliseconds. Each time, it subtracts the θ value of the preceding sample from the current value squared:
  A= I^2 - θ
- The value obtained is divided by the time constant and multiplied by 500 milliseconds.
  B = A * (0.5 sec / τ (in sec)
- This value is added to the preceding θ to obtain the current
  θ = θ + B

The value of θ is calculated as a % of the maximum value.

The **Thermal Image Trip** output is activated when the corresponding θ value reaches the value:

$$\theta_{TRIP} = Imax^2$$

The **Thermal Image Trip** signal resets when θ descends below:

$$\theta_{RST\_TRIP} = \theta_{TRIP} * \text{Connection\_PermissionSetting (\%) / 100}$$

The **Thermal Image Alarm** output is activated when the θ value reaches the value:

$$\theta_{ALARM} = \theta_{TRIP} * \text{AlarmSetting(\%) / 100}$$

The **Thermal Image Alarm** signal resets when θ descends below:

$$\theta_{RST\_ALARM} = 0.95 * \theta_{ALARM}$$

After applying a current **I** and starting with a current value of zero, the trip time is:

$$t = \tau \cdot Ln \frac{I^2}{I^2 - I_{max}{}^2}$$

If you start with a preliminary Ip current level, the operating time is:

$$t = \tau \cdot Ln \frac{I^2 - I_p{}^2}{I^2 - I_{max}{}^2}$$

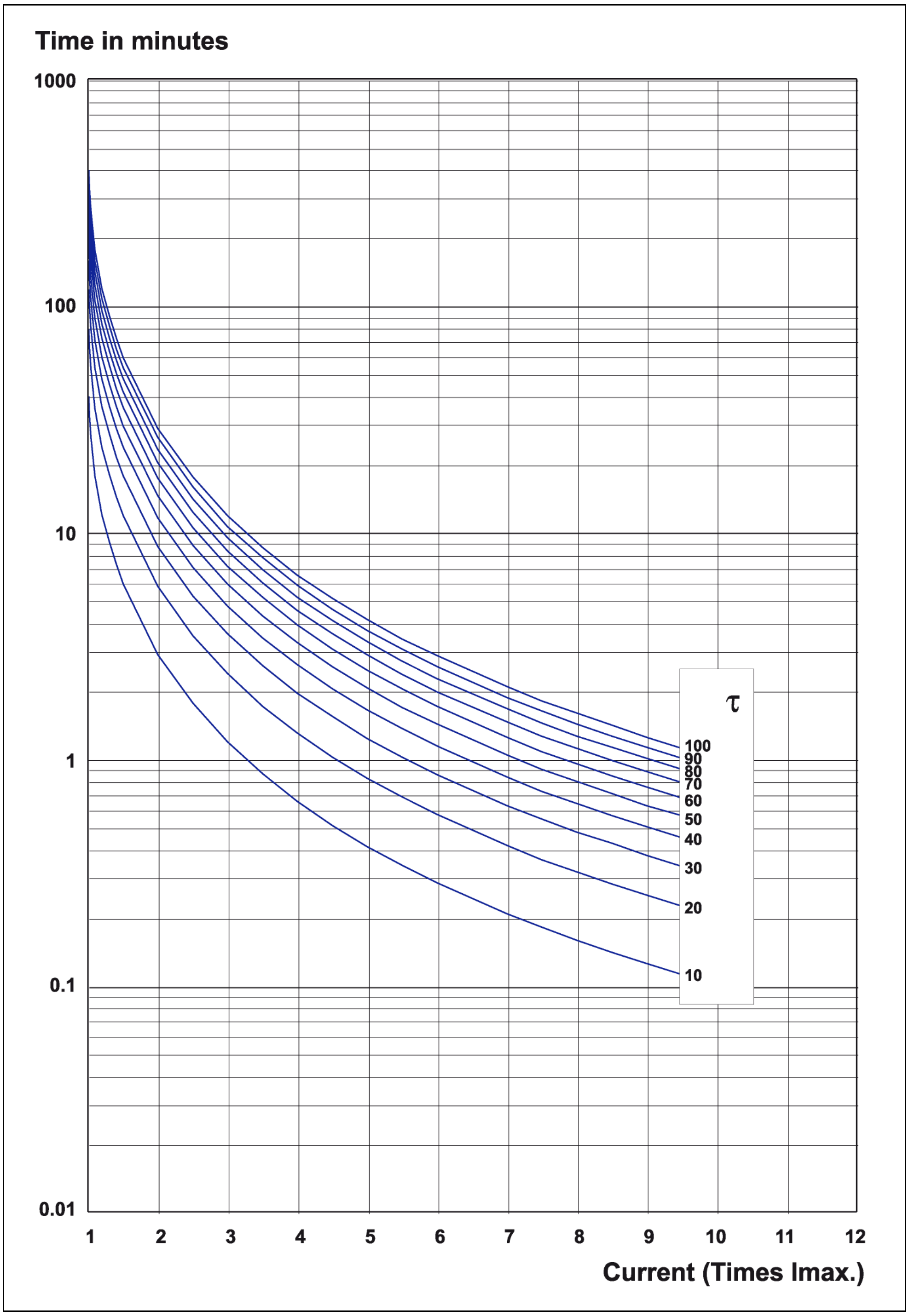

Figure 3.12.2 Operating Time Curves of the Thermal Image Unit.

3.12.2 Applying the Thermal Image Function

On most occasions, electric system faults generate currents higher than the rated current of the system's elements. In these cases the thermal effects can quickly produce damages.

The protections that are regularly used in these cases use overcurrent, causing trips both instantly and after a timed sequence using inverse "current / time" characteristics or set fixed times. However, in some applications, this protection system presents certain limitations.

An example might be a system with two transformers set in parallel powering the same bus, each of them running at loads below the rated load. If one of the transformers is out of service, the other transformer steps in and takes on the full load, very likely running at a load above its rated load.

With an overcurrent protection it can be disconnected in a very short period of time even when power transformers are designed to run with excess loads for several minutes without suffering any damage. During this period of time, there is no possibility of performing any action to reset the situation.

Given its operating principle, the Thermal Image Unit is highly indicated in these types of situations. In general, it can be said that this function is complementary to other protection types for cables or all kinds of machines (transformers, generators, etc.).

3.12.3 Thermal Image Unit Settings

Thermal Image Unit			
Setting	**Range**	**Step**	**By Default**
Enable	YES / NO		NO
Type of Device	0: Lines 1: Motor 2: Transformer		0: Lines
Constant ζ1 Line Heating Xfmer Fan On Motor On	0.5 - 300 min	0.01 min	0.5 min
Constant ζ2 Line Cooling Xfmer Fan Off Motor Off	0.5 - 300 min	0.01 min	0.5 min
Max. Operating Current	(0.20 - 2.5) In	0.01A	5.00 A
Alarm Level	50 - 100 %	1 %	50 %
Reset Threshold	50 - 90 %	1 %	80 %
Motor Scaling Factor	1 - 10	1	1
Thermal Memory Enable	YES / NO		NO

- **Thermal Image Unit: HMI Access (DLX-A Model)**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - OPEN POLE LOGIC
2 - ACTIVATE GROUP	2 - RECLOSER	2 - OVERCURRENT
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN PHASE DETECTOR
4 - INFORMATION	...	4 - CT SUPERVISION
		5 - THERMAL IMAGE
		6 - COLD LOAD
		7 - BREAKER FAILURE
		8 - POLE DISCREPANCY
		9 - PHASE SELECTOR
		10 - PROTECTION LOGIC

0 - LINE DIFFERENTIAL	**0 - THERMAL IMG. ENA**
1 - OPEN POLE LOGIC	**1 - TYPE OF DEVICE**
2 - OVERCURRENT	**2 - CONSTANT 1**
...	**3 - CONSTANT 2**
5 - THERMAL IMAGE	**4 - MAX. SUST. CURR.**
...	**5 - ALARM LEVEL**
	6 - RESET THRESHOLD
	7 - MOTOR CONSTANT
	8 - THERMAL MEMORY

- **Thermal Image Unit: HMI Access (DLX-B Model)**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	4 - OVERCURRENT
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - LINE DIFFERENTIAL	**0 - THERMAL IMG. ENA**
1 - FUSE FAILURE	**1 - TYPE OF DEVICE**
2 - DEAD LINE DETECTOR	**2 - CONSTANT 1**
...	**3 - CONSTANT 2**
10 - THERMAL IMAGE	**4 - MAX. SUST. CURR.**
...	**5 - ALARM LEVEL**
	6 - RESET THRESHOLD
	7 - MOTOR CONSTANT
	8 - THERMAL MEMORY

3.12.4 Digital Inputs of the Thermal Image Module

Table 3.12-1: Digital Inputs of the Thermal Image Module		
Name	**Description**	**Function**
C_CONST_T	Change Thermal Constant	Its activation changes the constant in the thermal image unit.
RST_MEM_T	Thermal Image Reset Input	Its activation resets the memorized value.
IN_BLK_THERM	Thermal Image Blocking Input	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
ENBL_THERM	Thermal Image Enable Input	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”

3.12.5 Auxiliary Outputs and Events of the Thermal Image Module

Table 3.12-2: Auxiliary Outputs and Events of the Thermal Image Module		
Name	**Description**	**Function**
C_CONST_T	Change Thermal Constant	The same as for the digital input.
RST_MEM_T	Thermal Image Reset Input	The same as for the digital input.
AL_THERM	Thermal Image Alarm	Alarm of the unit.
TRIP_THERM	Thermal Image Trip	Trip of the unit.
TRIP_THERMM	Thermal Image Masked Trip	Trip of the unit affected by its trip mask.
IN_BLK_THERM	Thermal Image Blocking Input	The same as for the digital input.
ENBL_THERM	Thermal Image Enable Input	The same as for the digital input.
THERM_ENBLD	Thermal Image Enabled	Indication of enabled or disabled status of the unit.

3.12.6 Thermal Image Unit Test

Before performing this test, the protection should be turned off and then back on to reset the thermal level. A current greater than the set maximum sustained current (I_{max}) is applied through phase A. The trip time must be:

$$t = \tau \cdot Ln \frac{(I \pm 1\%)^2}{(I \pm 1\%)^2 - I_{max}{}^2}$$

where τ is the set time constant ζ1.

An example: a time constant without ventilation of 0.5 minutes and a maximum current of 5 A. A current of 6 A is injected in phase A of the first winding. The time transpired until the unit trips must be between 33.05 s and 38.18 s.

3.13 Voltage Elements

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3.13.6.b Undervoltage Elements Test 3.13-12

3.13.1 Undervoltage Elements

DLX-B IEDs have three Phase Undervoltage Elements (27F1, 27F2 and 27F3). They operate when the RMS values of the voltages measured (phase-ground voltages) reach a given value. This value is set simultaneously for the three voltages in each unit.

The undervoltage elements have an associated logic which can be controlled with a setting in which you select between the following two possible types of operation (see figure 3.13.1):

- **AND**: the (27F) element trips when the three associated Undervoltage Elements (V1, V2 and V3) comply with the trip condition.
- **OR**: the (27F) element trips when one or more of the three associated Undervoltage Elements (V1, V2 or V3) comply with the trip condition.

Pickup occurs for a given Undervoltage Element when the value measured is equal to or less than one times the set value, and resets at a selectable percentage (greater) above the setting.

The Undervoltage Element Pickup enables the timing function. This is done by applying increments on a meter that picks up the element when it times out. The time setting included allows selecting a **Fixed Time** timing sequence.

When the RMS exceeds the set pickup, a rapid reset of the integrator occurs. The activation of the output requires the pickup to continue operating throughout the integration. Any reset leads the integrator to its initial conditions so that a new operation initiates the time count from zero.

An analog input can be assigned to the logic signal that blocks the trip signaling of the Undervoltage Phase Elements, thus disabling the output if this signal is activated.

The Undervoltage Elements will be blocked whenever the **Any Pole Open** (**OR_P_OP**) or **Blocking Due to Fuse Failure** (**BLK_FF**) signals, originating from the Open Pole Logic and Fuse Failure Detector, respectively, are activated.

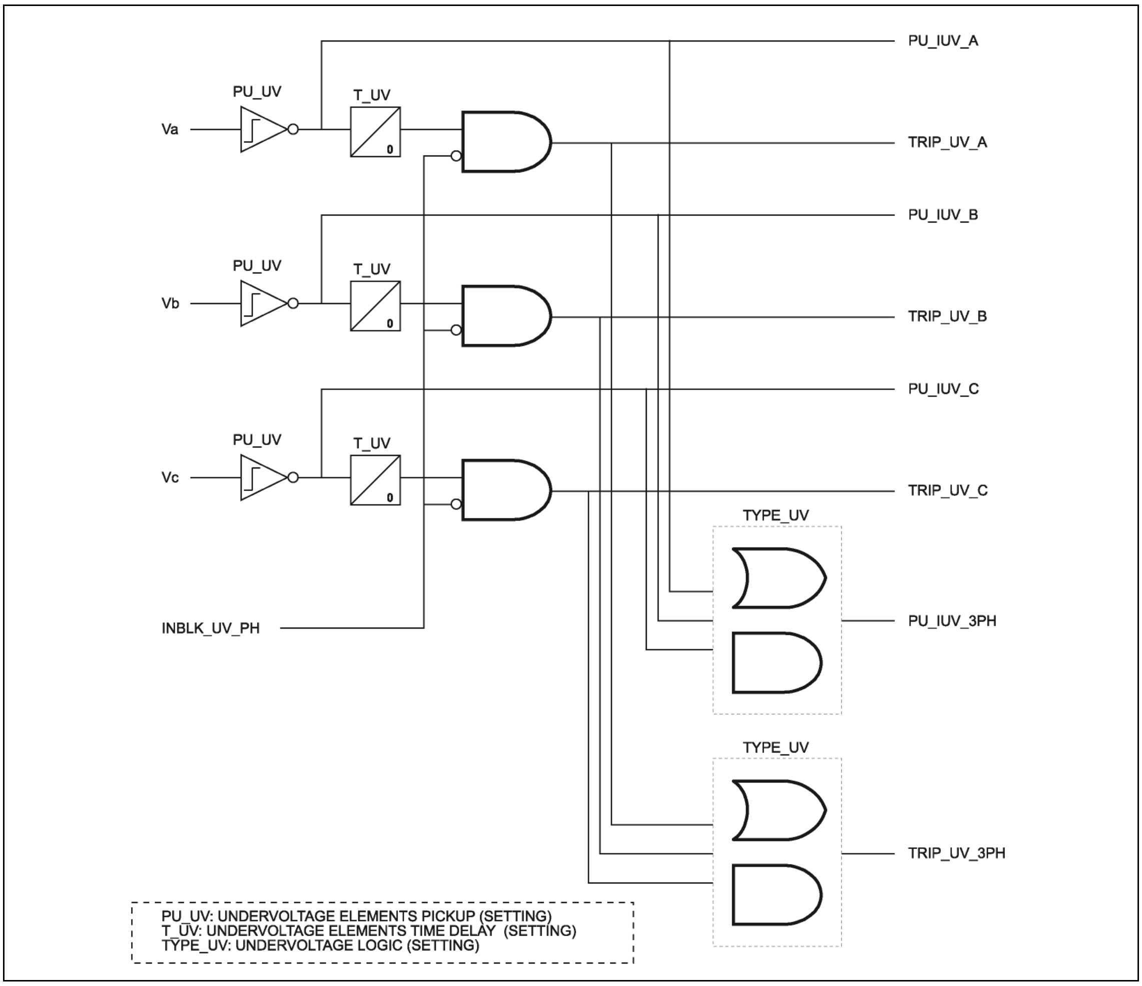

Figure 3.13.1 Block Diagram of Undervoltage Elements.

3.13.2 Overvoltage Elements

DLX-B IEDs have the following overvoltage elements:

- Three Phase Overvoltage Elements (59F1, 59F2 and 59F3).
- Two Ground Overvoltage elements (59N1 and 59N2).

3.13.2.a Phase Overvoltage Elements

They operate when the RMS values of the voltages measured (phase-ground voltages) reach a given value. This value is set simultaneously for the three voltages in each unit.

The Overvoltage Elements have an associated logic which can be controlled with a setting in which you select between the following two possible types of operation (see figure 3.13.2):

- **AND**: the (59F) element trips when the three associated Undervoltage Elements (V1, V2 and V3) comply with the trip condition.
- **OR**: the (59F) element trips when one or more of the three associated Undervoltage Elements (V1, V2 or V3) comply with the trip condition.

Pickup occurs for a given Overvoltage Element when the value measured is greater than one times the set value, and resets at a selectable percentage (less) of the setting.

The Overvoltage Element Pickup enables the timing function. This is done by applying increments on a meter that picks up the element when it times out. The time setting included allows selecting a fixed time timing sequence.

When the RMS falls below the pickup setting, a rapid reset of the integrator occurs. The activation of the output requires the pickup to continue operating throughout the integration. Any reset leads the integrator to its initial conditions so that a new operation initiates the time count from zero.

You can assign an analog input to the logic signal that blocks the trip signaling of the Overvoltage Phase Elements, thus disabling the output if this signal is activated.

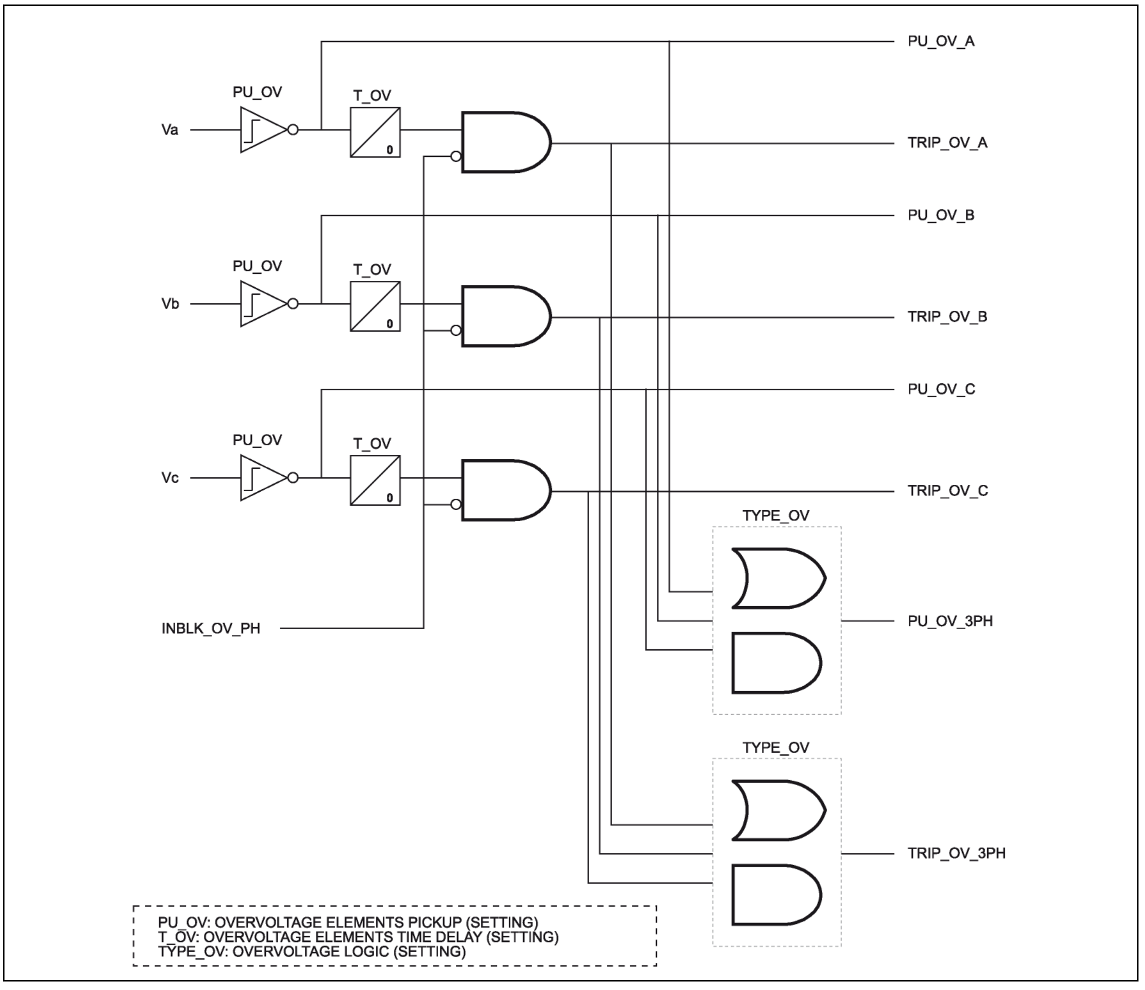

Figure 3.13.2 Block Diagram of Overvoltage Elements.

3.13.2.b Ground Overvoltage Elements

Ground OVERVOLTAGE ELEMENTS are made up of an Instantaneous Overvoltage Element with an additional independent adjustable timer.

The ground voltage is calculated using data from the three phase voltages. The RMS value of this ground voltage, which is the operating magnitude of the level detector, is calculated with the phase voltages as follows:

$$\overline{V_N} = \overline{V_A} + \overline{V_B} + \overline{V_C}$$

The adjustable output of this detector is the pickup signal of elements 59N1 and 59N2. It initializes an adjustable timer, whose output, combined with the blocking signal of the unit, in the AND gate is taken as the element's output. See figure 3.13.3.

The Ground Overvoltage Elements will be blocked whenever the **Any Pole Open** (**OR_P_OP**) or **Blocking Due to Fuse Failure** (**BLK_FF**) signals, originating from the **Open Pole Logic** and from the **Fuse Failure Detector**, respectively, are activated.

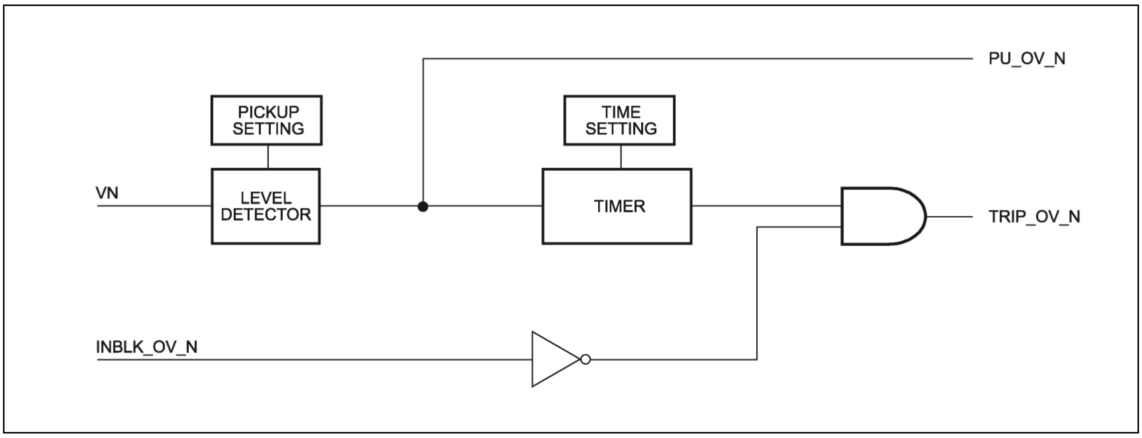

Figure 3.13.3 Block Diagram of a Ground Overvoltage Element.

Each element picks up when the RMS value of the zero sequence voltage exceeds 1 times the set pickup value and resets with a selectable value percentage (lower) of the setting.

Elements 59N1 and 59N2 can program **Block Trip** inputs, which prevents the operation of the element if this input is activated before the trip is generated. If activated after the trip, it resets. To be able to use these logic input signals, it is necessary to program the status contact inputs defined as **Block Trip**.

3.13.3 Voltage Elements Settings

Voltage Reset			
Setting	**Range**	**Step**	**By default**
Phase Overvoltage Elements Reset	50 - 99% of setting	1%	95%
Ground Overvoltage Elements Reset	50 - 99% of setting	1%	95%
Phase Undervoltage Elements Reset	101 - 150% of setting	1%	105%

Phase Overvoltage (Elements 1, 2 and 3)			
Setting	**Range**	**Step**	**By default**
Enable	YES / NO		NO
Pickup	20 - 300 V	0.01 V	70 V
Time Delay	0 - 300 s	0.01 s	0 s
Tripping Logic	OR / AND		OR

Phase Undervoltage (Elements 1, 2 and 3)			
Setting	**Range**	**Step**	**By default**
Enable	YES / NO		NO
Pickup	10 - 300 V	0.01 V	40 V
Time Delay	0 - 300 s	0.01 s	0 s
Tripping Logic	OR / AND		OR

Ground Overvoltage (Elements 1 and 2)			
Setting	**Range**	**Step**	**By default**
Enable	YES / NO		NO
Pickup	2 - 150 V	0.01 V	10 V
Time Delay	0 - 300 s	0.01 s	0 s

- **Voltage Protection: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	4 - OVERCURRENT
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - LINE DIFFERENTIAL	
1 - FUSE FAILURE	**0 - VOLTAGE RESET**
2 - DEAD LINE DETECTOR	**1 - PHASE OVERVOLTAGE**
...	**2 - GROUND OVERVOLTAGE**
5 - VOLTAGE	**3 - PHASE UNDERVOLTAGE**
...	

0 - VOLTAGE RESET	**0 - PH. UV RESET**
1 - PHASE OVERVOLTAGE	**1 - PH OV RESET**
2 - GROUND OVERVOLTAGE	**2 - GND OV RESET**
3 - PHASE UNDERVOLTAGE	

0 - VOLTAGE RESET	**0 - UNIT 1**	**0 - PH. OV ENABLE**
1 - PHASE OVERVOLTAGE	**1 - UNIT 2**	**1 - VOLTAGE TYPE**
2 - GROUND OVERVOLTAGE	**2 - UNIT 3**	**2 - PH. OV PICKUP**
3 - PHASE UNDERVOLTAGE		**3 - PH. OV DELAY**
		4 - OUTPUT LOGIC PH OV

0 - VOLTAGE RESET		**0 - GND OV ENABLE**
1 - PHASE OVERVOLTAGE	**0 - UNIT 1**	**1 - GND OV PICKUP**
2 - GROUND OVERVOLTAGE	**1 - UNIT 2**	**2 - GND OV DELAY**
3 - PHASE UNDERVOLTAGE		

0 - VOLTAGE RESET		**0 - PH. UV ENABLE**
1 - PHASE OVERVOLTAGE	**0 - UNIT 1**	**1 - VOLTAGE TYPE**
2 - GROUND OVERVOLTAGE	**1 - UNIT 2**	**2 - PH. UV PICKUP**
3 - PHASE UNDERVOLTAGE	**2 - UNIT 3**	**3 - PH. UV DELAY**
		4 - OUTPUT LOGIC PH UV

3.13.4 Digital Inputs and Events of the Voltage Modules

Table 3.13-1: Digital Inputs and Events of the Voltage Modules

Name	Description	Function
INBLK_UV1_PH	Phase Undervoltage Element 1 Block Input	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
INBLK_UV2_PH	Phase Undervoltage Element 2 Block Input	
INBLK_UV3_PH	Phase Undervoltage Element 3 Block Input	
INBLK_OV_PH1	Phase Overvoltage Element 1 Block Input	
INBLK_OV_PH2	Phase Overvoltage Element 2 Block Input	
INBLK_OV_PH3	Phase Overvoltage Element 3 Block Input	
INBLK_OV_N1	Ground Overvoltage Element 1 Block Input	
INBLK_OV_N2	Ground Overvoltage Element 2 Block Input	
ENBL_UV_PH1	Phase Undervoltage Element 1 Enable Input	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a "1."
ENBL_UV_PH2	Phase Undervoltage Element 2 Enable Input	
ENBL_UV_PH3	Phase Undervoltage Element 3 Enable Input	
ENBL_OV_PH1	Phase Overvoltage Element 1 Enable Input	
ENBL_OV_PH2	Phase Overvoltage Element 2 Enable Input	
ENBL_OV_PH3	Phase Overvoltage Element 3 Enable Input	
ENBL_OV_N1	Ground Overvoltage Element 1 Enable Input	
ENBL_OV_N2	Ground Overvoltage Element 2 Enable Input	

3.13.5 Digital Outputs and Events of the Voltage Modules

Table 3.13-2: Digital Outputs and Events of the Voltage Modules

Name	Description	Function
PU_IUV1_A	Phase A Undervoltage Element 1 Pickup	Pickup of the undervoltage and overvoltage elements and start of the time count. Three-phase pickups are those that are generated after the chosen AND or OR algorithm.
PU_IUV2_A	Phase A Undervoltage Element 2 Pickup	
PU_IUV3_A	Phase A Undervoltage Element 3 Pickup	
PU_IUV1_B	Phase B Undervoltage Element 1 Pickup	
PU_IUV2_B	Phase B Undervoltage Element 2 Pickup	
PU_IUV3_B	Phase B Undervoltage Element 3 Pickup	
PU_IUV1_C	Phase C Undervoltage Element 1 Pickup	
PU_IUV2_C	Phase C Undervoltage Element 2 Pickup	
PU_IUV3_C	Phase C Undervoltage Element 3 Pickup	
PU_IUV1_3PH	Three-Phase Undervoltage Element 1 Pickup	
PU_IUV2_3PH	Three-Phase Undervoltage Element 2 Pickup	
PU_IUV3_3PH	Three-Phase Undervoltage Element 3 Pickup	
PU_OV1_A	Phase A Overvoltage Element 1 Pickup	
PU_OV2_A	Phase A Overvoltage Element 2 Pickup	
PU_OV3_A	Phase A Overvoltage Element 3 Pickup	
PU_OV1_B	Phase B Overvoltage Element 1 Pickup	
PU_OV2_B	Phase B Overvoltage Element 2 Pickup	
PU_OV3_B	Phase B Overvoltage Element 3 Pickup	
PU_OV1_C	Phase C Overvoltage Element 1 Pickup	
PU_OV2_C	Phase C Overvoltage Element 2 Pickup	
PU_OV3_C	Phase C Overvoltage Element 3 Pickup	
PU_OV1_N	Ground Overvoltage Element 1 Pickup	
PU_OV2_N	Ground Overvoltage Element 2 Pickup	

Table 3.13-2: Digital Outputs and Events of the Voltage Modules		
Name	**Description**	**Function**
PU_OV1_3PH	Three-Phase Overvoltage Element 1 Pickup	Pickup of the undervoltage and overvoltage elements and start of the time count. Three-phase pickups are those that are generated after the chosen AND or OR algorithm.
PU_OV2_3PH	Three-Phase Overvoltage Element 2 Pickup	
PU_OV3_3PH	Three-Phase Overvoltage Element 3 Pickup	
TRIP_UV1_A	Phase A Undervoltage Element 1 Trip	Trip of the undervoltage and overvoltage elements. The three-phase trips are those that are generated after the chosen AND or OR algorithm.
TRIP_UV2_A	Phase A Undervoltage Element 2 Trip	
TRIP_UV3_A	Phase A Undervoltage Element 3 Trip	
TRIP_UV1_B	Phase B Undervoltage Element 1 Trip	
TRIP_UV2_B	Phase B Undervoltage Element 2 Trip	
TRIP_UV3_B	Phase B Undervoltage Element 3 Trip	
TRIP_UV1_C	Phase C Undervoltage Element 1 Trip	
TRIP_UV2_C	Phase C Undervoltage Element 2 Trip	
TRIP_UV3_C	Phase C Undervoltage Element 3 Trip	
TRIP_UV1_3PH	Three-Phase Undervoltage Element 1 Trip	
TRIP_UV2_3PH	Three-Phase Undervoltage Element 2 Trip	
TRIP_UV3_3PH	Three-Phase Undervoltage Element 3 Trip	
TRIP_OV1_A	Phase A Overvoltage Element 1 Trip	
TRIP_OV2_A	Phase A Overvoltage Element 2 Trip	
TRIP_OV3_A	Phase A Overvoltage Element 3 Trip	
TRIP_OV1_B	Phase B Overvoltage Element 1 Trip	
TRIP_OV2_B	Phase B Overvoltage Element 2 Trip	
TRIP_OV3_B	Phase B Overvoltage Element 3 Trip	
TRIP_OV1_C	Phase C Overvoltage Element 1 Trip	
TRIP_OV2_C	Phase C Overvoltage Element 2 Trip	
TRIP_OV3_C	Phase C Overvoltage Element 3 Trip	
TRIP_OV1_N	Ground Overvoltage Element 1 Trip	
TRIP_OV2_N	Ground Overvoltage Element 2 Trip	
TRIP_OV1_3PH	Three-Phase Overvoltage Element 1 Trip	
TRIP_OV2_3PH	Three-Phase Overvoltage Element 2 Trip	
TRIP_OV3_3PH	Three-Phase Overvoltage Element 3 Trip	

Table 3.13-2: Digital Outputs and Events of the Voltage Modules		
Name	**Description**	**Function**
UV_PH1_ENBLD	Phase Undervoltage Element 1 Enabled	Indication of enabled or disabled status of the voltage elements.
UV_PH2_ENBLD	Phase Undervoltage Element 2 Enabled	
UV_PH3_ENBLD	Phase Undervoltage Element 3 Enabled	
OV_PH1_ENBLD	Phase Overvoltage Element 1 Enabled	
OV_PH2_ENBLD	Phase Overvoltage Element 2 Enabled	
OV_PH3_ENBLD	Phase Overvoltage Element 3 Enabled	
OV_N1_ENBLD	Ground Overvoltage Element 1 Enabled	
OV_N2_ENBLD	Ground Overvoltage Element 2 Enabled	
INBLK_UV1_PH	Phase Undervoltage Element 1 Block Input	The same as for the Digital Inputs.
INBLK_UV2_PH	Phase Undervoltage Element 2 Block Input	
INBLK_UV3_PH	Phase Undervoltage Element 3 Block Input	
INBLK_OV_PH1	Phase Overvoltage Element 1 Block Input	
INBLK_OV_PH2	Phase Overvoltage Element 2 Block Input	
INBLK_OV_PH3	Phase Overvoltage Element 3 Block Input	
INBLK_OV_N1	Ground Overvoltage Element 1 Block Input	
INBLK_OV_N2	Ground Overvoltage Element 2 Block Input	
ENBL_UV_PH1	Phase Undervoltage Element 1 Enable Input	The same as for the Digital Inputs.
ENBL_UV_PH2	Phase Undervoltage Element 2 Enable Input	
ENBL_UV_PH3	Phase Undervoltage Element 3 Enable Input	
ENBL_OV_PH1	Phase Overvoltage Element 1 Enable Input	
ENBL_OV_PH2	Phase Overvoltage Element 2 Enable Input	
ENBL_OV_PH3	Phase Overvoltage Element 3 Enable Input	
ENBL_OV_N1	Ground Overvoltage Element 1 Enable Input	
ENBL_OV_N2	Ground Overvoltage Element 2 Enable Input	

3.13.6 Voltage Elements Test

3.13.6.a Overvoltage Elements Test

Before testing the Overvoltage Unit, all the voltage units that are not being tested must be disabled.

- **Pickup and Reset**

The desired pickup values for the relevant unit are set and their activation is checked by operating any output configured for this purpose. This can also be verified by checking the pickup flags of the menu **Information** - **Status** - **Units**. This verification can also be made by checking that the trip flag of this menu is activated if the unit trips.

Table 3.13-3: Pickup and Reset of the Overvoltage Elements

Setting of the unit	Pickup		Reset	
	Maximum	Minimum	Maximum	Minimum
X	1.03 x X	0.97 x X	(RST setting + 0.03) x X	(RST setting - 0.03) x X

Where the value “RST setting” corresponds to the setting in per unit of the **Unit Reset** for the Overvoltage Units.

- **Operating Times**

Outputs C1-C2 are used to verify them [See figure 3.13.4].

Fixed Time or Instantaneous

The **Pickup** setting is increased 20%. Operating time should be the selected time setting ±1% or ±20 ms (whichever is greater). A setting of 0 ms will have an operating time between 20 and 25 ms.

3.13.6.b Undervoltage Elements Test

Before testing the undervoltage unit, all the voltage units that are not being tested must be disabled.

- **Pickup and Reset**

The desired pickup values for the relevant unit are set and their activation is checked by operating any output configured for this purpose. This can also be verified by checking the pickup flags of the menu **Information** - **Status** - **Units**. This verification can also be made by checking that the trip flag of this menu is activated if the unit trips.

Table 3.13-4:Pickup and Reset of the Undervoltage Elements

Setting of the unit	Pickup		Reset	
	Maximum	Minimum	Maximum	Minimum
X	1.03 x X	0.97 x X	(RST setting + 0.03) x X	(RST setting - 0.03) x X

Where the value “RST setting” is the setting in per unit of the **Unit Reset** for the Undervoltage Units.

- **Operating Times**

Outputs F9-F10, F11-F12 and F13-F14 are used to verify them (See figure 3.13.4).

Fixed time or instantaneous

The **Pickup** setting is decreased 20%. Operating time should be the selected time setting ±1% or ±20 ms (whichever is greater). A setting of 0 ms will have an operating time between 20 and 25 ms.

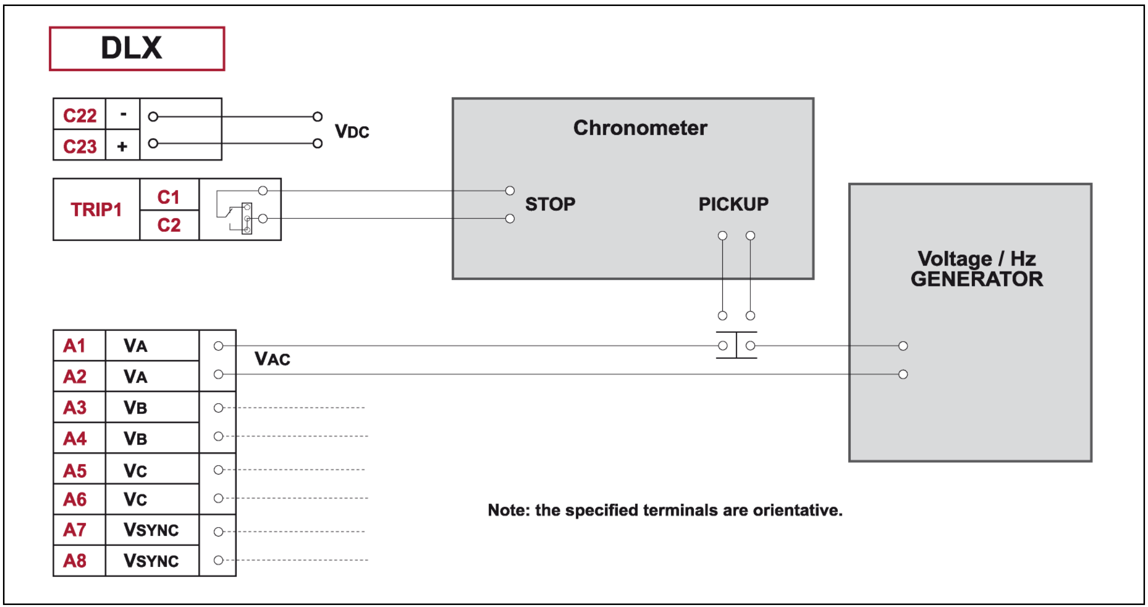

Figure 3.13.4 Operating Time Test Setup.

3.14 Frequency Elements

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3.14.3	Underfrequency Elements	3.14-3
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3.14.1 Introduction

DLX-B IEDs have the following frequency elements:

- Three Overfrequency Elements (81M1, 81M2 and 81M3).
- Three Underfrequency Elements (81m1, 81m2 and 81m3).
- Three Rate of Change Elements (81D1, 81D2 and 81D3).

The Underfrequency, Overfrequency and Rate of Change Elements have their own settings for each function and a set of settings common to all of them. The shared settings are:

- **Inhibition Voltage**. This setting checks that the voltage is above a set value. If so, it allows the Frequency Elements to meter and to operate. Otherwise, it gives a frequency value of zero and the Frequency Elements are inhibited.
- **Activation half-waves**. This is the number of half-waves that must meet the pick-up conditions to activate such pick-up of the Frequency Units. This setting is used to filter those transient frequency variations (duration of several half-waves) that can appear when the frequency of the system changes and could accidentally activate the unit trip
- **Reset cycles**. This is the number of cycles during which there may not exist pick-up conditions so that the Frequency Elements already picked up will reset (pick-up deactivation). When the Frequency Elements have been picked up and have not yet operated, the pick-up conditions may disappear during a brief instant (due to transient frequency variations). This setting indicates how long these conditions may disappear without resetting the element. For example, if the rate of change should be falling below -0.5 Hz/s and during an instant it only goes down to -0.45 Hz/s; it may not be desirable that the pick-up of the protection function reset if the time the pick-up condition disappears is very short.
- **Load shedding algorithm**. There is an option to have the Frequency Elements 1 operate in pairs, an Underfrequency or Rate of Change Element with an Overfrequency Element, to perform a Load Shedding Scheme. This operation mode permits 1 load shedding level. For more than one level, Programmable Logic should be configured using the signals from the rest of Frequency Units.
- **Load Shedding Type**. Either the Underfrequency or the Rate of Change Element can be selected to initiate the load shedding.

All the elements have a disabling counter. This counter, of approximately 50 milliseconds, operates when, while the element is tripped, the function is deactivated either by the inhibition voltage, by setting or because the breaker opens.

All the elements have a time module that can be set to instantaneous. It has the following settings:

- Pickup.
- Time.

Figure 3.14.1 is the block diagram of one of the Frequency Elements.

Associated with the level detection block, there is a setting for the pickup value: if the element is the Overfrequency Element, and the value measured exceeds the setting value a given quantity, the element picks up; if it is the Underfrequency Element, it picks up whether or not the value measured is less than the setting value a given quantity.

Activation of the pickup enables the timing function. This is done by applying increments on a meter that picks up the element when it times out.

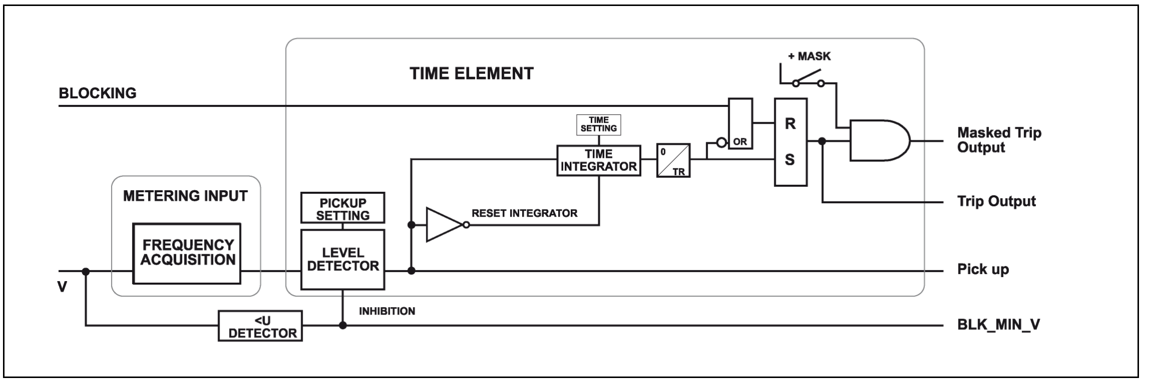

Figure 3.14.1 Block Diagram of a Frequency Element.

3.14.2 Overfrequency Elements

Overfrequency Elements operate on the measured frequency value of input voltage V_A or V_{AB}.

Pickup occurs when the value measured coincides with or surpasses the pickup value (100% of the setting) during a number of half-waves equal to or greater than the **Activation Half-Waves** setting, and resets when the frequency falls below 10mHz of this setting for a time equal to or greater than the **Reset Time** setting. This **Reset Time** setting indicates how long the fault conditions must disappear after a fault for the trip to reset.

3.14.3 Underfrequency Elements

Underfrequency Elements operate on the measured frequency value of input voltage V_A or V_{AB}.

Pickup occurs when the value measured coincides with or is below the pickup value (100% of the setting) during a number of half-waves equal to or greater than the setting of **Activation Half-Waves**, and resets when the frequency goes up above 10mHz of this setting for a time equal to or greater than the **Reset Time** setting. The same as in the Overfrequency Element, this **Reset Time** setting indicates how long the fault conditions must disappear after a fault for the trip to reset.

3.14.4 Rate of Change Elements

Rate of Change Elements operate on the measured frequency value of input voltage V_A or V_{AB}.

Apart from the rest of settings common to all frequency units (see “Introduction”), the algorithm of these elements uses the following specific settings for the Rate of Change function (in addition to the enabling permission of each of them):

- **Frequency Pickup**. Frequency value below which this magnitude must be to consider the rate of its change.
- **Rate of Change Pickup**. Instantaneous value of the rate of change in respect of the time for which the element is to pick up.
- **Timing**. Time during which the pick-up must remain for the element to activate.
- **Reset Time**. Time during which the unit pickup must keep deactivated to reset the unit trip.

dF/dT value is calculated every time that the voltage analog input Va makes itself zero by obtaining the variation of the frequency between the current value and the one available 5 half-waves before.

The unit will pick-up only when the value of dF/dT is higher than the one set as **Rate of Change Pickup** (setting value + 0,05Hz/s in absolute value) for a selected period of time equal to the **Activation Half-Waves** setting value minus 7 half-waves. In detail, taking into account that the relay requires 2 half-waves to calculate the frequency value accurately and 5 half-waves to calculate the dF/dT value, the time period from the frequency variation to the pickup of the unit is that called as **Activation Half-Waves**. If the value of the **Activation Half-Waves** setting is less than 10 half-waves, then the Frequency Rate of Change unit will always consider a value equal to 10. Refer to the example regarding the operation of the unit pick-up.

In the algorithm, the Rate of Change must be equal to or less than a given adjustable value (Frequency Unit Pickup) for a time equal to or greater than the **Activation Half-Waves** setting before the rate of change is taken into account. This algorithm checks the frequency and the rate of change of the frequency separately. For the element to operate, the pick-up conditions must exist for both. See figure 3.14.2.

The figure below depicts the operation mode for the Rate of Change function:

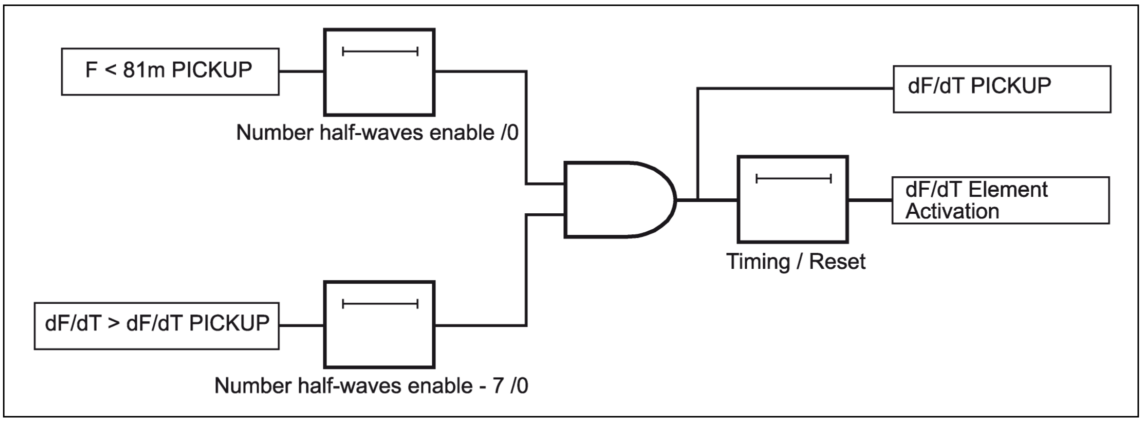

Figure 3.14.2 Logic Diagram of a Rate of Change Element.

Example regarding the operation of the unit pickup:

Activation Half-Waves = 3
Frequency Unit Pickup = 49.8 Hz
Df/Dt Unit Pickup = -1 Hz/S
Time Delay = 0.1 S

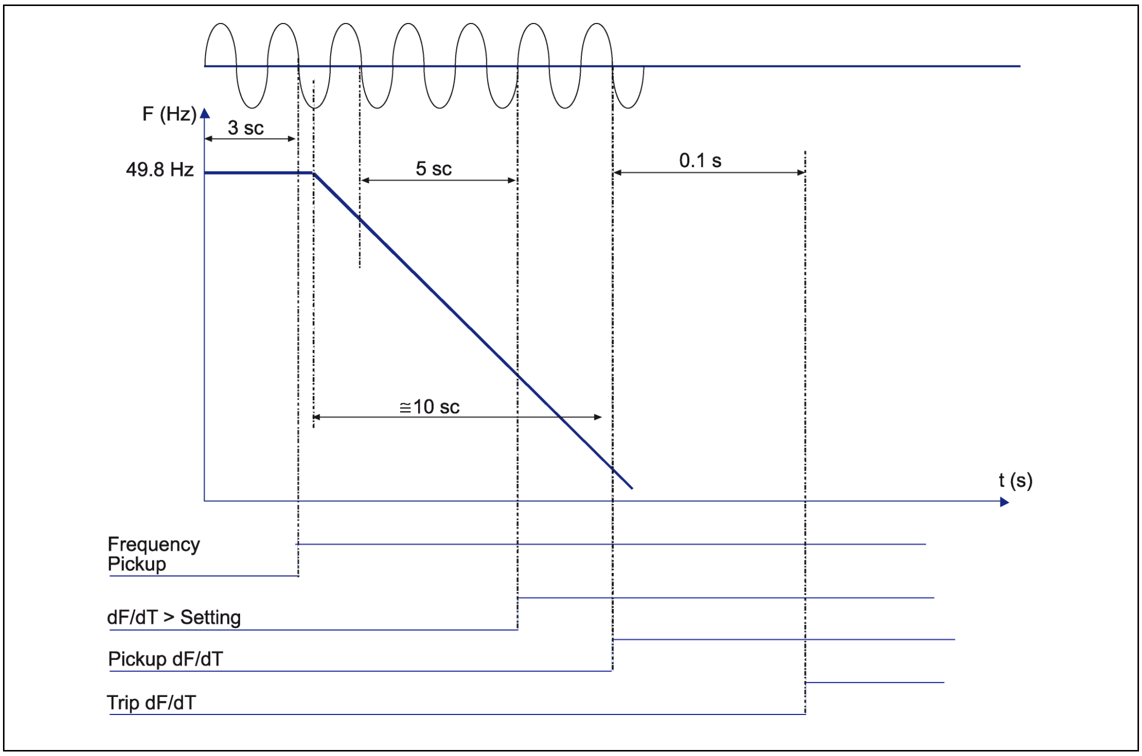

Figure 3.14.3 Example Regarding the Operation of the unit Pickup.

3.14.5 Elements Blocking Logic

Each of the Frequency Elements has a **Blocking Logic Input**. Activating this input prevents the activation of the output of the corresponding Frequency element, as shown in figure 3.14.1.

These logic input signals can be associated to the relay's status contact inputs by configuring the input settings.

3.14.6 Undervoltage Element for Blocking

This element supervises the functioning of the Frequency Elements, impeding their operation for measured voltage below the set value.

The element picks up when the measured voltage value coincides with or is less than the pickup value (100% of the setting), and resets with a value greater than or equal to 105% of the setting, provided this condition is maintained for at least 10 consecutive cycles. These 10 verification cycles provide assurance that the voltage is stable.

In any case, the relay cannot measure frequency for voltage less than 2 volts. Therefore, in these conditions, the Frequency and Phase Angle Measuring (Out-of-Step) Elements do not work.

3.14.7 Load Shedding Algorithm

As described in previous units, the frequency measurement is obtained from the input voltage Va or Vab. The voltage is obtained from the side still having voltage after load shedding (generally the busbar side). This way, after load shedding the device continues to measure frequency in order to reconnect the load.

The IED provides a control function for performing 1 load shedding and reset step. Frequency Elements 1 can be set to operate in pairs, with Underfrequency 1 or Rate of Change 1 Element paired with the Overfrequency 1 Element, to perform a load shedding and reset control function.

For more steps, it is necessary to use the Programmable Logic and configure it using the signals generated by the rest of the Frequency Elements. The reason for this is that the designed control function takes into account the position of the breaker. If more steps are configured, the user can choose to follow a similar operating scheme by requiring information about the position of other breakers, or choose a completely different logic. The control function logic for Frequency Elements 1 is described below:

Closure Command (**CLOSE**) and **Open Command** (**OPEN**) can be given as long as switching permission (**MsIr**) are set to **YES** and the Frequency Elements are not blocked (**INBLK**). The operation of the Overfrequency Element is conditioned by the prior operation of the Underfrequency or Rate of Change Element (**TRIP_U**) and the Open Breaker (**IN_BKR**) status, as indicated in the logic diagram of figure 3.14.4 (See Note 1).

The **TRIP_U** signal is not a logic output of the load shedding module nor does it generate an event. To make it available, it must be generated in the Programmable Logic.

After the equipment generates the Closure Command, either because underfrequency has existed or the rate of change has acted and the breaker has opened, it restores the condition of another possible close.

If the **Trip Circuit Supervision Failure** (**FAIL_SUPR**) signal is activated having complied with all the conditions that allow after an overfrequency the closure by Load Shedding Element (**IN_BKR** = 1 and **TRIP_U** = 1) is activated, when the close by Load Shedding Element is activated its close command will not be generated and the close command annulled (**CCR**) signal will be activated.

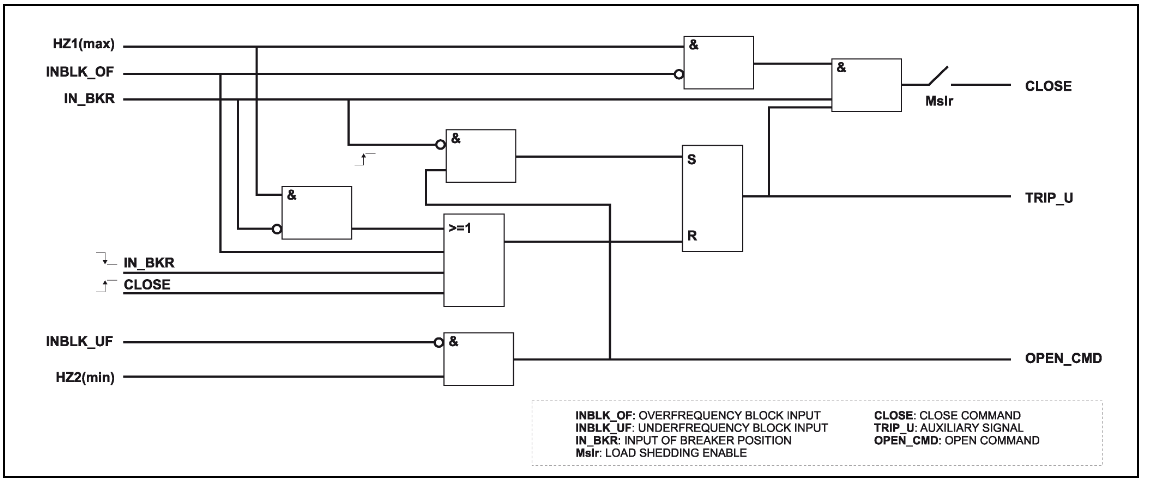

Figure 3.14.4 Under/Overfrequency Load Shedding Algorithm Logic Diagram.

Note 1: both startup and activation of the maximum frequency unit are conditioned by the previous action of the Underfrequency unit or Rate-of-Change (TRIP_U) and by the status of the Open Breaker (IN_BKR), as indicated in the logic diagram of figure 3.14.4. The Overfrequency Unit resets when the frequency level complies with the reset conditions of the unit (point 3.14.2), or when the TRIP_U signal is reset.

3.14.8 Application of the Frequency Elements

The frequency variations are caused by an incorrect balance between generation and load, which is generally due to the following reasons:

- Division of the system into parts.
- Imbalance between load and generation due to lack of foresight or deficient programming.
- Loss of generation, trip of busses or important interconnection lines.

Frequency is a reliable indicator of an overload condition. Any decrease in frequency is caused by an excess load. With this condition, minimum frequency relays must be used to shed load and thus balance generation with consumption and avoid a major collapse of the system. When frequency recovers its rated value and the electricity system stabilizes, the loads that have been shed are restored. This restoration operation is performed by the maximum frequency relay.

A decrease in frequency produces instability in the electricity system and can damage the generators. The greatest danger, however, lies in steam turbines. Variations in the rotational speed of the turbine produce vibrations and consequently the blades suffer mechanical fatigue. Since this is cumulative deterioration, the problem will increase whenever the turbine is in an underfrequency condition.

When the variation in the frequency is small, the imbalance can be corrected by regulating the generators. With large frequency variations, however, the generator cannot correct it. As a result, the frequency starts decreasing, risking a trip of the generation sets. If this frequency drop is not corrected, an irreversible process begins and leads to a general blackout.

In situations of strong generation deficit, the only way to restore balance is to selectively disconnect loads. The loads are usually disconnected when the frequency has fallen below fixed values to give the generation sets time to react to frequency drops with speed regulators. When the frequency drop is very quick, this action is not effective enough. Loads have to be disconnected according to the variation in the frequency in respect of time, that is, by basing calculations and operation on the rate of change in respect of time.

Underfrequency relays are usually installed in substations and industrial plants that require a load shedding system, where the loads are fed exclusively by local generation or by a combination of its own generators and a transmission line derivation. In this second case [part (A) of figure 3.14.5], if a fault occurs in the transmission line, the system's own generators will be overloaded, and the frequency will drop quickly. This plant needs a fast load shedding system controlled by frequency relays.

If the transmission line supplies more than one plant and is disconnected at a remote end [part (B) of figure 3.14.5], the plant, with its own generation, is in a situation to supply power to the line while its own frequency is decreasing. This power flow output can be avoided with protection relays against power inversion but, unless the whole overload is eliminated, the frequency relay must disconnect the lower priority local loads.

Independently of generation, frequency protections are also used in distribution substations that require a load shedding system with a disconnection priority scale. Priorities are also taken into account as frequency is recovered while restoring the loads.

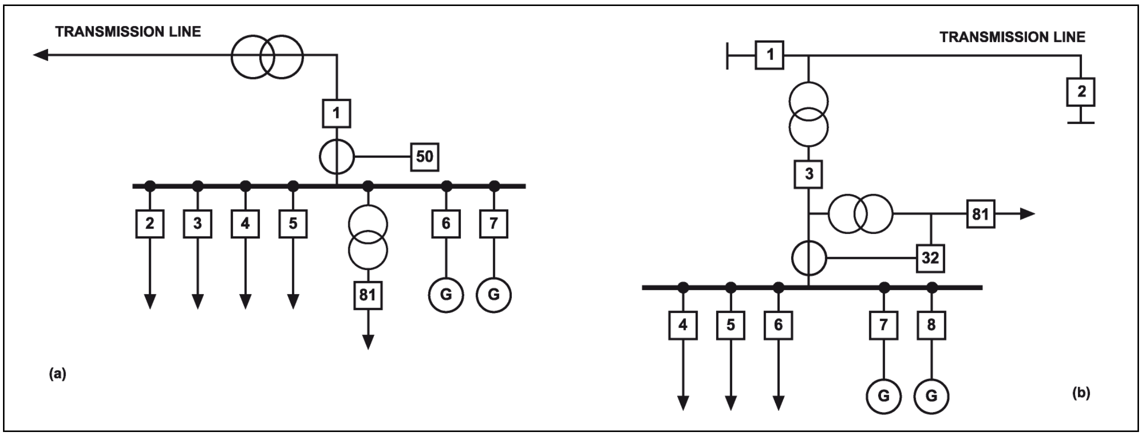

Figure 3.14.5 Load Shedding System in an Industrial Plant.

3.14.9 Frequency Elements Settings

Common Settings			
Setting	**Range**	**Step**	**By Default**
Inhibit Voltage	2 - 150 V	1 V	2 V
Pickup Activation Timer	3 - 30 half cycles	1 half cycle	6 half cycles
Reset Time	0 - 10 cycles	1 cycle	0 cycle
Load Shedding 1 Enable	YES / NO		NO
Load Shedding Type	0 - Underfrequency 1 - Rate of Change		0 - Underfreq.

Overfrequency Elements 1, 2, 3 and 4			
Setting	**Range**	**Step**	**By Default**
Enable	YES / NO		NO
Pickup	40 - 70 Hz	0.01 Hz	70 Hz
Time Delay	0.00 - 300 s	0.01 s	0 s
Reset Time	0.00 - 300 s	0.01 s	2 s

Underfrequency Elements 1, 2, 3 and 4			
Setting	**Range**	**Step**	**By Default**
Enable	YES / NO		NO
Pickup	40 - 70 Hz	0.01 Hz	40 Hz
Time Delay	0.00 - 300 s	0.01 s	0 s
Reset Time	0.00 - 300 s	0.01 s	2 s

Frequency Rate of Change Elements 1, 2, 3 and 4			
Setting	**Range**	**Step**	**By Default**
Enable	YES / NO		NO
Underfrequency Pickup	40 - 70 Hz	0.01 Hz	40 Hz
Frequency ROC Pickup	(-0.5) - (-10.00) Hz/s	0.01 Hz/s	-1 Hz/s
Time Delay	0.00 - 300 s	0.01 s	0 s
Reset Time	0.00 - 300 s	0.01 s	2 s

- **Frequency Protection: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	4 - OVERCURRENT
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - LINE DIFFERENTIAL	**0 - INHIBIT VOLTAGE**
1 - FUSE FAILURE	**1 - PICK UP TIME**
2 - DEAD LINE DETECTOR	**2 - DROPOUT TIME**
...	**3 - LOAD SHEDD 1 ENBL**
6 - FREQUENCY	**4 - LOAD SHEDDNG TYPE**
...	**5 - OVERFREQUENCY**
	6 - UNDERFREQUENCY
	7 - ROCOF

Overfrequency

0 - INHIBIT VOLTAGE		
1 - PICK UP TIME		
2 - DROPOUT TIME		0 - OVERFREQ. ENABLE
3 - LOAD SHEDD 1 ENBL	0 - UNIT 1	1 - OVERFREQ. PICKUP
4 - LOAD SHEDDNG TYPE	1 - UNIT 2	2 - OVERFREQ. DELAY
5 - OVERFREQUENCY	2 - UNIT 3	3 - DROPOUT TIME
6 - UNDERFREQUENCY		
7 - ROCOF		

Underfrequency

0 - INHIBIT VOLTAGE		
1 - PICK UP TIME		
2 - DROPOUT TIME		
3 - LOAD SHEDD 1 ENBL		0 - UNDERFREQ. ENABLE
4 - LOAD SHEDDNG TYPE	0 - UNIT 1	1 - UNDERFREQ. PICKUP
5 - OVERFREQUENCY	1 - UNIT 2	2 - UNDERFREQ. DELAY
6 - UNDERFREQUENCY	2 - UNIT 3	3 - DROPOUT TIME
7 - ROCOF		

Rate-of-Change

0 - INHIBIT VOLTAGE		
1 - PICK UP TIME		
2 - DROPOUT TIME		
3 - LOAD SHEDD 1 ENBL		0 - ROC FREQ. ENABLE
4 - LOAD SHEDDNG TYPE		1 - UNDERFREQ. PICKUP
5 - OVERFREQUENCY	0 - UNIT 1	2 - ROCOF PICKUP
6 - UNDERFREQUENCY	1 - UNIT 2	3 - ROC FREQ. DELAY
7 - ROCOF	2 - UNIT 3	4 - DROPOUT TIME

3.14.10 Digital Inputs of the Frequency Modules

Table 3.14-1: Digital Inputs of the Frequency Modules

Name	Description	Function
IN_BLK_OF1	Overfrequency Element 1 Block Input	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
IN_BLK_OF2	Overfrequency Element 2 Block Input	
IN_BLK_OF3	Overfrequency Element 3 Block Input	
IN_BLK_OF4	Overfrequency Element 4 Block Input	
IN_BLK_UF1	Underfrequency Element 1 Block Input	
IN_BLK_UF2	Underfrequency Element 2 Block Input	
IN_BLK_UF3	Underfrequency Element 3 Block Input	
IN_BLK_UF4	Underfrequency Element 4 Block Input	
IN_BLK_ROC1	Rate Of Change Element 1 Block Input	
IN_BLK_ROC2	Rate Of Change Element 2 Block Input	
IN_BLK_ROC3	Rate Of Change Element 3 Block Input	
IN_BLK_ROC4	Rate Of Change Element 4 Block Input	
ENBL_OF1	Overfrequency Element 1 Enable Input	Activation of this input puts the element into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”
ENBL_OF2	Overfrequency Element 2 Enable Input	
ENBL_OF3	Overfrequency Element 3 Enable Input	
ENBL_OF4	Overfrequency Element 4 Enable Input	
ENBL_UF1	Underfrequency Element 1 Enable Input	
ENBL_UF2	Underfrequency Element 2 Enable Input	
ENBL_UF3	Underfrequency Element 3 Enable Input	
ENBL_UF4	Underfrequency Element 4 Enable Input	
ENBL_ROC1	Rate Of Change Element 1 Enable Input	
ENBL_ROC2	Rate Of Change Element 2 Enable Input	
ENBL_ROC3	Rate Of Change Element 3 Enable Input	
ENBL_ROC4	Rate Of Change Element 4 Enable Input	

3.14.11 Auxiliary Outputs and Events of the Frequency Modules

Table 3.14-2: Auxiliary Outputs and Events of the Frequency Modules

Name	Description	Function
PU_OF1	Overfrequency Element 1 Pickup	Pickup of the Frequency Elements and start of the time count.
PU_OF2	Overfrequency Element 2 Pickup	
PU_OF3	Overfrequency Element 3 Pickup	
PU_OF4	Overfrequency Element 4 Pickup	
PU_UF1	Underfrequency Element 1 Pickup	
PU_UF2	Underfrequency Element 2 Pickup	
PU_UF3	Underfrequency Element 3 Pickup	
PU_UF4	Underfrequency Element 4 Pickup	
PU_ROC1	Rate Of Change Element 1 Pickup	
PU_ROC2	Rate Of Change Element 2 Pickup	
PU_ROC3	Rate Of Change Element 3 Pickup	
PU_ROC4	Rate Of Change Element 4 Pickup	
TRIP_OF1	Overfrequency Element 1 Trip	Trip of the Frequency Elements.
TRIP_OF2	Overfrequency Element 2 Trip	
TRIP_OF3	Overfrequency Element 3 Trip	
TRIP_OF4	Overfrequency Element 4 Trip	
TRIP_UF1	Underfrequency Element 1 Trip	
TRIP_UF2	Underfrequency Element 2 Trip	
TRIP_UF3	Underfrequency Element 3 Trip	
TRIP_UF4	Underfrequency Element 4 Trip	
TRIP_ROC1	Rate Of Change Element 1 Trip	
TRIP_ROC2	Rate Of Change Element 2 Trip	
TRIP_ROC3	Rate Of Change Element 3 Trip	
TRIP_ROC4	Rate Of Change Element 4 Trip	
CLS_LS1	Close Of Load Shedding Element 1	Close of the overfrequency element 1 when it is configured for load shedding.
TRIP_OF1M	Overfrequency Element 1 Masked Trip	Trip of the frequency elements affected by their corresponding trip masks.
TRIP_OF2M	Overfrequency Element 2 Masked Trip	
TRIP_OF3M	Overfrequency Element 3 Masked Trip	
TRIP_OF4M	Overfrequency Element 4 Masked Trip	
TRIP_UF1M	Underfrequency Element 1 Masked Trip	
TRIP_UF2M	Underfrequency Element 2 Masked Trip	
TRIP_UF3M	Underfrequency Element 3 Masked Trip	
TRIP_UF4M	Underfrequency Element 4 Masked Trip	
TRIP_ROC1M	Rate Of Change Element 1 Masked Trip	
TRIP_ROC2M	Rate Of Change Element 2 Masked Trip	
TRIP_ROC3M	Rate Of Change Element 3 Masked Trip	
TRIP_ROC4M	Rate Of Change Element 4 Masked Trip	

Table 3.14-2: Auxiliary Outputs and Events of the Frequency Modules		
Name	**Description**	**Function**
CLS_LS1M	Masked Close Of Load Shedding Element 1	Close of the overfrequency element 1 when it is configured for load shedding affected by their corresponding mask.
IN_BLK_OF1	Overfrequency Element 1 Block Input	The same as for the Digital Inputs.
IN_BLK_OF2	Overfrequency Element 2 Block Input	
IN_BLK_OF3	Overfrequency Element 3 Block Input	
IN_BLK_OF4	Overfrequency Element 4 Block Input	
IN_BLK_UF1	Underfrequency Element 1 Block Input	
IN_BLK_UF2	Underfrequency Element 2 Block Input	
IN_BLK_UF3	Underfrequency Element 3 Block Input	
IN_BLK_UF4	Underfrequency Element 4 Block Input	
IN_BLK_ROC1	Rate Of Change Element 1 Block Input	
IN_BLK_ROC2	Rate Of Change Element 2 Block Input	
IN_BLK_ROC3	Rate Of Change Element 3 Block Input	
IN_BLK_ROC4	Rate Of Change Element 4 Block Input	
ENBL_OF1	Overfrequency Element 1 Enable Input	The same as for the Digital Inputs.
ENBL_OF2	Overfrequency Element 2 Enable Input	
ENBL_OF3	Overfrequency Element 3 Enable Input	
ENBL_OF4	Overfrequency Element 4 Enable Input	
ENBL_UF1	Underfrequency Element 1 Enable Input	
ENBL_UF2	Underfrequency Element 2 Enable Input	
ENBL_UF3	Underfrequency Element 3 Enable Input	
ENBL_UF4	Underfrequency Element 4 Enable Input	
ENBL_ROC1	Rate Of Change Element 1 Enable Input	
ENBL_ROC2	Rate Of Change Element 2 Enable Input	
ENBL_ROC3	Rate Of Change Element 3 Enable Input	
ENBL_ROC4	Rate Of Change Element 4 Enable Input	
OF1_ENBLD	Overfrequency Element 1 Enable Input	Enable or disable status indication of the frequency elements.
OF2_ENBLD	Overfrequency Element 2 Enable Input	
OF3_ENBLD	Overfrequency Element 3 Enable Input	
OF4_ENBLD	Overfrequency Element 4 Enable Input	
UF1_ENBLD	Underfrequency Element 1 Enable Input	
UF2_ENBLD	Underfrequency Element 2 Enable Input	
UF3_ENBLD	Underfrequency Element 3 Enable Input	
UF4_ENBLD	Underfrequency Element 4 Enable Input	
ROC1_ENBLD	Rate Of Change Element 1 Enable Input	
ROC2_ENBLD	Rate Of Change Element 2 Enable Input	
ROC3_ENBLD	Rate Of Change Element 3 Enable Input	
ROC4_ENBLD	Rate Of Change Element 4 Enable Input	
BLK_MIN_V	Minimum Voltage Block	Blocking of Frequency and Phase Angle Measuring elements.

3.14.12 Frequency Elements Test

Before testing these elements, the voltage elements that are not being tested must be disabled.

- **Pickup and Reset of the Overfrequency and Underfrequency Elements**

Depending on the settings of the Frequency Elements (Overfrequency / Underfrequency), the pickups and resets must be within the margins indicated in Tables 3.14-3 and 3.14-4 for their rated voltage.

Table 3.14-3: Pickup and Reset of the Overfrequency Elements				
Setting	Pickup		Reset	
XHz	ΦA_MIN	ΦA_MAX	ΦR_MIN	ΦR_MAX
	X - 0.005Hz	X + 0.005Hz	(X - 0.01Hz) + 0.005Hz	(X – 0.01Hz) - 0.005Hz

Table 3.14-4: Pickup and Reset of the Underfrequency Elements				
Setting	Pickup		Reset	
XHz	ΦA_MIN	ΦA_MAX	ΦR_MIN	ΦR_MAX
	X + 0.005Hz	X - 0.005Hz	(X + 0.01Hz) - 0.005Hz	(X + 0.01Hz) + 0.005Hz

- **Voltage Reset**

The Frequency elements must reset within the margin indicated in table 3.14-5 for set voltage value X.

Table 3.14-5: Voltage Reset				
Setting	Pickup		Reset	
X	MAX	MIN	MAX	MIN
	1.03 x X	0.97 x X	1.08 x X	1.02 x X

- **Operating Times**

They are verified with trip outputs C1-C2.

To measure times, the voltage generator must be able to generate an up or down frequency ramp depending on the element to be tested as well as to provide an output to initiate a chronometer when it gets to the pickup frequency.

Operating times for a setting of Xs must be between (1.01 × X – 0.99 × X) or between (X + 20ms – X - 20ms). If the setting is 0, the operating time will be close to 60 ms.

In operating times, it is important how the frequency ramp is generated and when the chronometer starts. The frequency value of the signal generated should be very close to the threshold to test and generate the broadest step possible.

Without a frequency ramp generator, only the Overfrequency Element can be tested. Going from no voltage applied to applying voltage above the disable and the Overfrequency settings will yield a time value somewhat greater than with a frequency ramp.

- **Pickup and Reset of the Rate of Change Elements**

The Rate of Change Elements are configured with the following operation values:

81D1 Element	**0.5 Hz/s**
81D2 Element	**0.7 Hz/s**
81D3 Element	**0.9 Hz/s**
81D4 Element	**1 Hz/s**

They are all set to the same frequency value.

Frequency ramps are generated below the set frequency value and each ramp must operate with a margin of error not greater than 0.05 Hz/s.

3.15 Breaker Failure Unit

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3.15.1 Introduction

The **DLX** models incorporate one Breaker Failure Element. The Breaker Failure Unit detects malfunction of the breaker after a trip command is issued. A signal is generated to allow closing of other breakers contributing to the fault (those adjacent to that protected line and at the remote end).

The Breaker Failure Unit incorporates a retrip function whose objective is to send a new tripping command to the failed breaker before the open command directed toward the remaining breakers which may continue to feed the fault is generated. In order for the failed breaker to open with the retripping command before being actuated over the breakers of the adjacent lines, the timing of the breaker failure unit should be longer than that adjusted in the retrip function.

The Breaker Failure protection is provided with six phase current metering units, two for each of the phases, and one ground current metering unit. The two groups of phase metering units and the ground metering unit have independent pick up levels, with the following settings: **Phase Single-Phase Pick Up** (1 phase pick up), **Phase Three-Phase Pick Up** (2 phase pick up) and **Ground Pick Up**.

The main characteristic of the pickup detectors is its rapid reset time (5 ms).

The diagrams corresponding to the measuring units are those represented in Figures 3.15.1 and 3.15.2 and give the breaker failure pick up signals as the output.

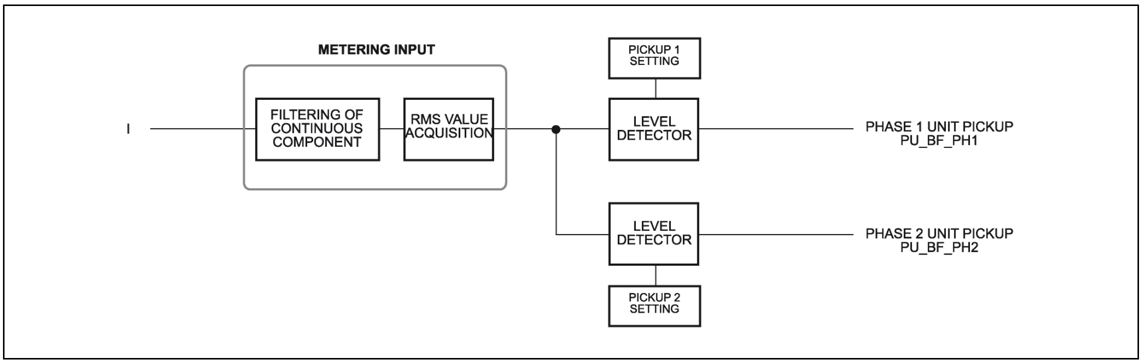

Figure 3.15.1 Diagram of the Phase Current Metering Units of the Breaker Failure.

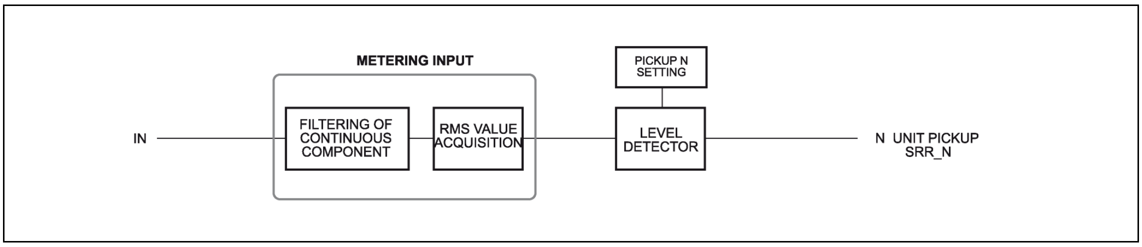

Figure 3.15.2 Block Diagram of the Ground Current Metering Unit of the Breaker Failure.

3.15.2 Operation Logic of the Breaker Failure Unit. DLX-B Model

The operation logic of the Breaker Failure Unit for **DLX-B** Models is described in the following Figure. This logic is controlled by the pickup of the above-mentioned Phase and Ground Overcurrent Units together with a series of logic signals originating from other protection modules.

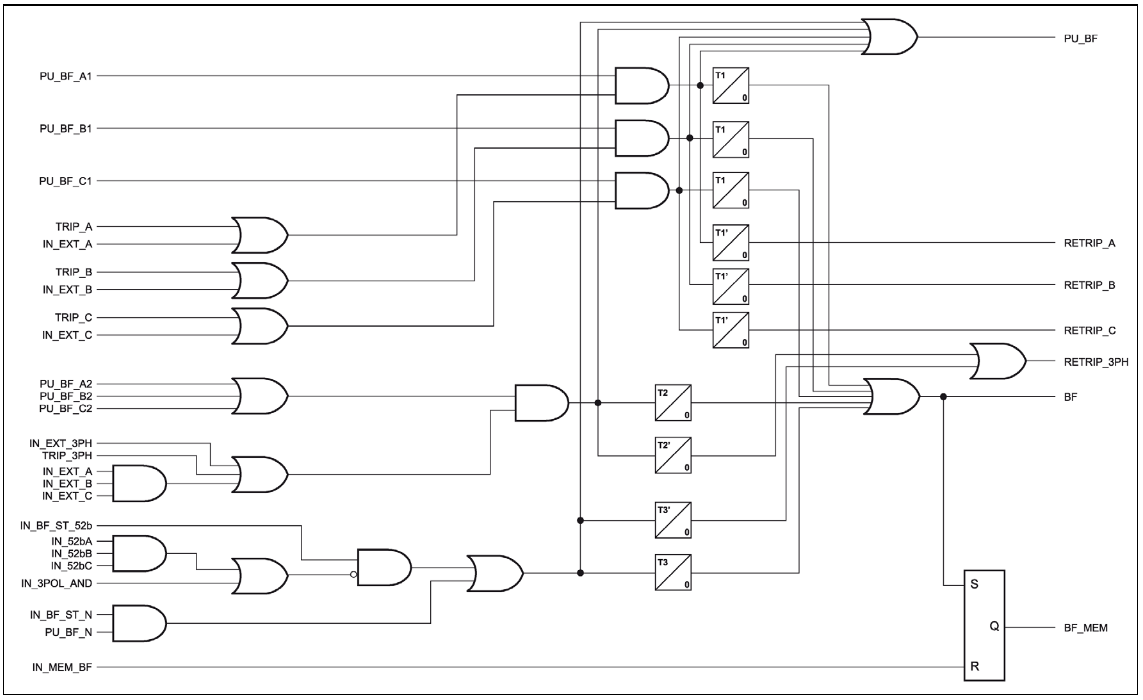

Figure 3.15.3 Logic Diagram of the Breaker Failure Unit (DLX-B Model).

The actuation of the Breaker Failure Unit (activation of the **BF** output) is memorized in a bistable element, activating the **BF_MEM** output. This signal will remain active even when **BF** is reset and only disappears through a reset command which will be issued through the activation of the **IN_MEM_BF** logic input.

The actuation process of the Breaker Failure Unit can be divided into three groups: **Single-Phase Tripping**, **Three-Phase Tripping with Phase Overcurrent** and **Three-Phase Tripping without Phase Overcurrent**.

3.15.2.a Single-Phase Tripping

The commencement of the Single-Phase Breaker Failure is produce by the activation of a single-phase tripping signal together with the pickup of the Single-Phase Current Detector associated with the tripped phase (faulted phase). The single-phase trip signals may be generated by the **DLX** itself (**A Pole Trip** (**TRIP_A**), **B Pole Trip** (**TRIP_B**) and **C Pole Trip** (**TRIP_C** signals), originating from the Single/Three-Phase Trip Logic, see 2.24) or originate from an external unit (**A Pole External Trip** (**IN_EXT_A**), **B Pole External Trip** (**IN_EXT_B**) and **C Pole External Trip** (**IN_EXT_C**) logic inputs).

The starting of the single-phase breaker failure activates the **T1** timers (**Single-Phase Breaker Failure Time**) and **T1'** (**Single-Phase Retripping Time**). The **T1'** timer output generates the retripping signal associated with the faulted phase -**A Pole Retripping** (**RETRIP_A**), **B Pole Retripping** (**RETRIP_B**), **C Pole Retripping** (**RETRIP_C**)-, in order to send a new tripping command to the failed breaker pole, before generating the **Breaker Failure** (**BF**) command. If the retripping command does not produce the aperture of the pole already tripped, the **T1** timer will reach the end, activating the **BF** (**Breaker Failure**) and **BF_MEM** (**Memorized Breaker Failure**) signals. The use of timers segregated by phase ensures the expiration of the T1 time before the activation of the breaker failure output in the event of evolving faults.

As was indicated previously, the most important characteristic of the current detectors is their rapid reset time, in order to stop the timer count as soon as the breaker opens and make the current disappear, not allowing the erroneous activation of **BF**. If the reset time is long, there is a risk of not stopping the timer in time, in spite of the disappearance of current, and cause the undue tripping of other breakers not belonging to the protected line.

3.15.2.b Three-Phase Tripping with Phase Overcurrent

The starting of the Three-Phase Trip Failure with Overcurrent is produced by the activation of a three-phase trip signal together with the pickup of any of the three-phase current detectors. The three-phase trip signal can be generated by the equipment itself (**Three-Phase Tripping** (**TRIP_3PH**), originating from the Single/Three-Phase Trip Logic, see 3.24) or by an external unit (AND logic output of **IN_EXT_A**, **IN_EXT_B** and **IN_EXT_C** or activation of **IN_EXT_3PH**).

The starting of the three-phase breaker failure with overcurrent activates the **T2** (**Three-Phase Breaker Failure Time**) and **T2'** (**Three-Phase Retripping Time**) timers. The **T2'** timer output generates the **Three-Phase Retripping** (**RETRIP_3PH**) signal in order to send a new trip command to the failed breaker, before generating the **Breaker Failure** (**BF**) command. If the retrip command does not produce the breaker aperture, the **T2** timer will reach the end, activating the **BF** (**Breaker Failure**) and **BF_MEM** (**Memorized Breaker Failure**) signals.

Given that polyphase faults require to be cleared more quickly than single-phase faults, in order to ensure the stability of the system, the **T2** time will be adjusted to a lower value than the **T1** time. Thus, when the trip is three phase, the breaker failure signal will always be activated on expiration of **T2** instead of **T1**.

The rapid reset time of the current detectors should again be pointed out.

3.15.2.c Three-Phase Tripping without Phase Overcurrent

The trip signals, of the equipment itself or of an external unit, which produce the commencement of a breaker failure, can be activated without the pickup of the phase current detection units. This situation may arise, in general, in case of any type of disturbance tripped by units which do not depend on the current metering, such as Voltage Units, Frequency, etc., or in case of faults in which the local contribution is very weak, as a result of the fault resistance being very high or the local source being weak.

There are two alternative routes to detect a breaker failure without overcurrent:

- **Detection Based on the Position of the Breaker Contacts**

The start of the Breaker Failure is produced with the activation of the **Contact Position Breaker Failure Start** (**IN_BF_ST_52b**) whenever any breaker pole remains closed (it is checked either that the AND of the three breaker position inputs is open (**IN_52bA**, **IN_52bB** and **IN_52bC**), deactivated or that the input of three open poles (**IN_3POL_AND**) is set at zero). The input can be configured with the trip outputs of the Frequency units, Overvoltage, Weak Infeed logic, etc.

- **Detection Based on a Ground Current Metering Unit**

The start of Breaker Failure is produced with the activation of the **IN_BF_ST_N** (**Ground Unit Breaker Failure Start** input) input together with the starting of the ground current detector. The **E_IFIN** input can be configured with the general tripping output of the equipment (**TRIP**) or with an external general tripping output (**IN_EXT** or OR of **IN_EXT_A**, **IN_EXT_B** and **IN_EXT_C**).

The start of the Three-Phase Breaker Failure without Phase Overcurrent starts the **T3** (**Three-Phase Breaker Failure Time without Overcurrent**) and **T3'** (**Three-Phase Retripping Time without Overcurrent**) timers. The **T3'** timer generates the **Three-Phase Retripping** (**RETRIP_3PH**) signal in order to send a new trip command to the failed breaker, before generating the **Breaker Failure** (**BF**) command. If the retrip command does not produce the aperture of the breaker, the **T3** timer will reach the end, activating the **BF** (**Breaker Failure**) and **BF_MEM** (**Memorized Breaker Failure**) signals.

3.15.3 Breaker Failure Element Operation Logic. DLX-A Model

The operation logic of the Breaker Failure Unit for **DLX-A** models is controlled by the pickup of the above-mentioned Phase and Ground Overcurrent Units together with a series of logic signals originating from other protection modules.

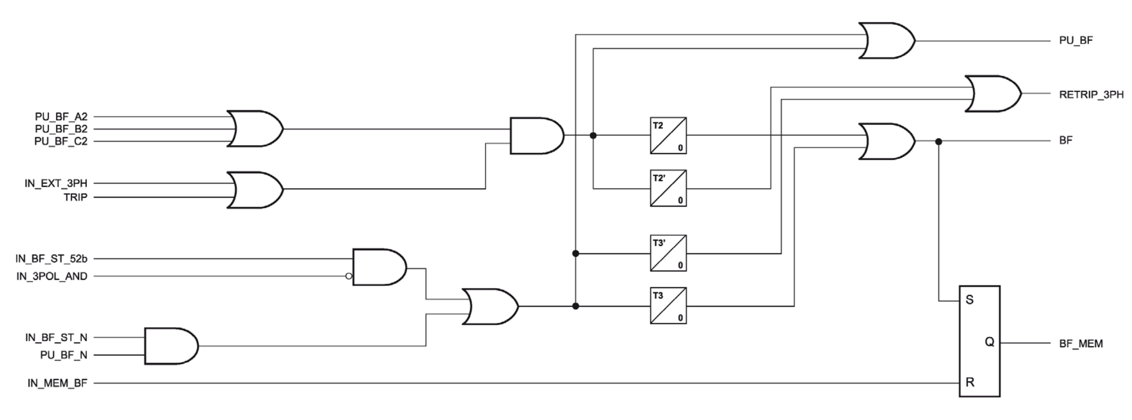

Figure 3.15.4 Logic Diagram of the Breaker Failure (DLX-A Model).

The actuation process of the Breaker Failure Unit in the **DLX-A** model will be similar to that corresponding to the **DLX-B** model, with the exception that the start of the single-phase breaker failure will not exist.

3.15.4 Internal Arc Detector

As a complement to the above-mentioned Breaker Failure Unit, the **DLX** equipment incorporates a logic which allows detecting the existence of an unextinguished internal arc.

If a breaker begins to open but remains jammed, the electric arc between the contacts may not be extinguished. The arc resistance may greatly reduce the fault current to the point of resetting the protection units and the trip signal. In this case, the Breaker Failure Unit would also be reset.

The presence of an unextinguished electric arc in a phase can be detected if the pole position contacts associated with that phase indicate that this is open and notwithstanding the current in this phase exceeds a determined threshold (**Internal Arc Detector Pick Up** setting).

The pickup of the Internal Arc Detector tends to adjust to below the pickup values of the current metering units used by the Breaker Failure function. The operation diagram of the Internal Arc Detector is shown to the right.

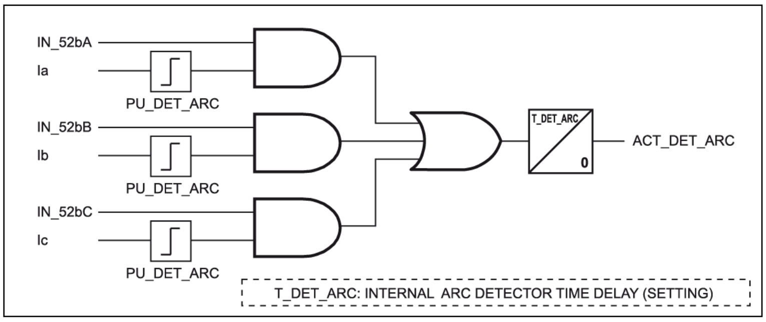

Figure 3.15.5 Logic Diagram of the Internal Arc Detector.

3.15.5 Breaker Failure Unit Settings

Breaker Failure Unit			
Setting	**Range**	**Step**	**By default**
Enable	YES / NO		NO
Single-Phase Pickup (DLX-B)	(0.02 - 2.4) In A	0.01 A	0.2 In
Three-Phase Pickup	(0.02 - 2.4) In A	0.01 A	0.2 In
Ground Pickup	(0.02 - 1.2) In A	0.01 A	0.1 In
Single-Phase Breaker Failure Time Delay (DLX-B)	0.05 - 2 s	0.01 s	0.5 s
Three Phase Breaker Failure Time Delay With Overcurrent	0.05 - 2 s	0.01 s	0.5 s
Three Phase Breaker Failure Time Delay Without Overcurrent	0.05 - 2 s	0.01 s	0.5 s
Single-Phase Breaker Failure Retripping Time Delay (DLX-B)	0.05 - 2 s	0.01 s	0.5 s
Three-Phase Breaker Failure Retripping Time Delay With Overcurrent	0.05 - 2 s	0.01 s	0.5 s
Three-Phase Breaker Failure Retripping Time Delay Without Overcurrent	0.05 - 2 s	0.01 s	0.5 s
Internal Arc Detector Enable	YES / NO		NO
Internal Arc Detector Pickup	(0.01 - 0.2) In A	0.01 A	0.01 In
Internal Arc Detector Time Delay	0.1 - 2 s	0.01 s	0.1 s

- **Breaker Failure Unit: HMI Access (DLX-A Model)**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - OPEN POLE LOGIC
2 - ACTIVATE GROUP	2 - RECLOSER	2 - OVERCURRENT
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN PHASE DETECTOR
4 - INFORMATION	...	4 - CT SUPERVISION
		5 - THERMAL IMAGE
		6 - COLD LOAD
		7 - BREAKER FAILURE
		8 - POLE DISCREPANCY
		9 - PHASE SELECTOR
		10 - PROTECTION LOGIC

0 - LINE DIFFERENTIAL	**0 - BF ENABLE**
1 - OPEN POLE LOGIC	**1 - THREE PHASE PU**
2 - OVERCURRENT	**2 - BF GROUND PICKUP**
...	**3 - 3 POLE BF DELAY**
7 - BREAKER FAILURE	**4 - 3POLE NOOC BF DLY**
...	**5 - 3 POLE RETRIP DELAY**
	6 - 3POLE RETRP NOOC DLY
	7 - ARC DET ENABLE
	8 - ARC DETEC PICK UP
	9 - ARC DETECTOR TIME

- **Breaker Failure Unit: HMI Access (DLX-B Model)**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	4 - OVERCURRENT
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - LINE DIFFERENTIAL	**0 - BF ENABLE**
1 - FUSE FAILURE	**1 - SINGLE PHASE PU**
2 - DEAD LINE DETECTOR	**2 - THREE PHASE PU**
...	**3 - BF GROUND PICKUP**
13 - BREAKER FAILURE	**4 - 1 POLE BF DELAY**
...	**5 - 3 POLE BF DELAY**
	6 - 3POLE NOOC BF DLY
	7 - 1 POLE RETRIP DELAY
	8 - 3 POLE RETRIP DELAY
	9 - 3POLE RETRP NOOC DLY
	10 - ARC DET ENABLE
	11 - ARC DETEC PICK UP
	12 - ARC DETECTOR TIME

3.15.6 Digital Inputs and Events of the Breaker Failure Module

Table 3.15-1: Digital Inputs and Events of the Breaker Failure Module

Name	Description	Function
ENBL_BF	Breaker Failure Element Enable Input	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”
IN_EXT_A	A Pole External Trip Input (DLX-B)	Activation of this input indicates the existence of a trip of A pole of the breaker generated by an external protection.
IN_EXT_B	B Pole External Trip Input (DLX-B)	Activation of this input indicates the existence of a trip of B pole of the breaker generated by an external protection.
IN_EXT_C	C Pole External Trip Input (DLX-B)	Activation of this input indicates the existence of a trip of C pole of the breaker generated by an external protection.
IN_EXT_3PH	Three-Phase External Trip Input	Activation of this input indicates the existence of a three-phase trip of the breaker generated by an external protection.
IN_EXT	External Trip Input (DLX-B)	Activation of this input indicates the existence of a trip of the breaker generated by an external protection.
IN_MEM_BF	Memorized Breaker Failure Reset Input	Activation of this input resets the memorized output of the breaker failure.
IN_BF_ST_52b	Contact Position Breaker Failure Start Input	Activation of this input produces the start of the breaker failure without overcurrent, whenever there is a breaker pole closed.
IN_BF_ST_N	Ground Unit Breaker Failure Start Input	Activation of this input produces the start of the breaker failure without overcurrent, provided that the neutral current detection unit is picked up.
ENBL_ARC	Internal Arc Detector Enable Input	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”

3.15.7 Digital Outputs and Events of the Breaker Failure Module

Table 3.15-2: Digital Outputs and Events of the Breaker Failure Module

Name	Description	Function
PU_BF_A1	A Phase Single-Phase B.F. Unit Pickup (DLX-B)	Pick up of the current metering unit for single-phase breaker failure detection in the corresponding phase.
PU_BF_B1	B Phase Single-Phase B.F. Unit Pickup (DLX-B)	
PU_BF_C1	C Phase Single-Phase B.F. Unit Pickup (DLX-B)	
PU_BF_A2	A Phase Three-Phase B.F. Unit Pickup	Pick up of the current metering unit for three-phase breaker failure detection in the corresponding phase.
PU_BF_B2	B Phase Three-Phase B.F. Unit Pickup	
PU_BF_C2	C Phase Three-Phase B.F. Unit Pickup	
PU_BF_N	Ground B.F. Unit Pickup	Pick up of the current metering unit for breaker failure detection without phase overcurrent.
PU_BF	Breaker Failure Pickup	Pick up of the Breaker Failure.
RETRIP_A	A Pole Retrip (DLX-B)	Retrip output of A pole of the breaker.
RETRIP_B	B Pole Retrip (DLX-B)	Retrip output of B pole of the breaker.
RETRIP_C	C Pole Retrip (DLX-B)	Retrip output of C pole of the breaker.
RETRIP_3PH	Three-Phase Retrip	Three-phase retrip output of the breaker.
BF	Breaker Failure	Activation of breaker failure.
BF_MEM	Memorized Breaker Failure	Activation of memorized breaker failure.
BF_ENBLD	Breaker Failure Unit Enabled	Indication of enabled or disabled status of the unit.
ACT_DET_ARC	Arc Detector Activation	Activation of the unit.
ARC_ENBLD	Internal Arc Detector Unit Enabled	Indication of enabled or disabled status of the unit.

Digital Outputs and Events of the Breaker Failure Module		
Name	**Description**	**Function**
ENBL_BF	Breaker Failure Element Enable Input	The same as for the Digital Inputs.
IN_EXT_A	A Pole External Trip Input (DLX-B)	The same as for the Digital Inputs.
IN_EXT_B	B Pole External Trip Input (DLX-B)	The same as for the Digital Inputs.
IN_EXT_C	C Pole External Trip Input (DLX-B)	The same as for the Digital Inputs.
IN_EXT_3PH	Three-Phase External Trip Input	The same as for the Digital Inputs.
IN_EXT	External Trip Input (DLX-B)	The same as for the Digital Inputs.
IN_MEM_BF	Memorized Breaker Failure Reset Input	The same as for the Digital Inputs.
IN_BF_ST_52b	Contact Position Breaker Failure Start Input	The same as for the Digital Inputs.
IN_BF_ST_N	Ground Unit Breaker Failure Start Input	The same as for the Digital Inputs.
ENBL_ARC	Internal Arc Detector Enable Input	The same as for the Digital Inputs.

3.15.8 Breaker Failure Unit Test

To verify the activation of the breaker failure element the **Information** - **Status** - **Measuring Elements** - **Breaker Failure** menu or in the ***ZIVercomPlus***® to **Status** - **Elements** - **Breaker Failure** should be accessed and the statuses of the breaker failure and memorized breaker failure flags should be contrasted.

To carry out the tests, in addition to the breaker failure element itself, the distance elements should be enabled (the remaining disabled elements).

The pickup levels of the breaker failure elements should be adjusted (single-phase, three-phase and ground pick up) at 0.5 A. Similarly, the single-phase, three-phase and three-phase without load breaker failure times should be adjusted to 0.5 s.

3.15.8.a Single-Phase Breaker Failure

Apply a single-phase fault in zone 1, such that the trip does not disconnect the current (with this being higher than 0.5 A). Verify that the **Breaker Failure** and **Memorized Breaker Failure** flags activate at 0.5 s.

Disconnect the current and verify that, although the breaker failure signal resets, the memorized breaker failure output does not reset until the **Memorized Breaker Failure Reset** signal is activated.

Adjust Distance Elements as reverse direction and apply a current of 1 A to phase A. Activate the **IN_EXT_A** (**A Phase External Protection Actuation**) input and verify that the **Breaker Failure** and **Memorized Breaker Failure** flags activate at 0.5 s.

Disconnect the current and verify that, although the breaker failure signal resets, the **Memorized Breaker Failure** Output does not reset until the **Memorized Breaker Failure Reset** signal is activated.

3.15.8.b Three-Phase Breaker Failure

Readjust the Distance Elements as forward direction.

Apply a two-phase fault in zone 1, such that the trip does not disconnect the currents (with these being higher than 0.5 A). Verify that the **Breaker Failure** and **Memorized Breaker Failure** flags activate at 0.5 s.

Disconnect the currents and verify that although the **Breaker Failure** signal resets, the **Memorized Breaker Failure** Output does not reset until the **Memorized Breaker Failure Reset** signal is activated.

Adjust the Distance Elements as reverse direction and apply a current of 1 A to A and B phases. Activate the **IN_EXT_3PH** (**External Three-Phase Trip**) input or the **IN_EXT_A**, **IN_EXT_B** and **IN_EXT_C** inputs simultaneously (**A Phase**, **B Phase** and **C Phase External Protection Actuation**) and verify that the **Breaker Failure** and **Memorized Breaker Failure** flags activate at 0.5 s.

Disconnect the current and verify that, although the **Breaker Failure** signal resets, the **Memorized Breaker Failure** output does not reset until the **Memorized Breaker Failure Reset** signal is activated.

3.15.8.c Three-Phase Breaker Failure without Load

Disable the Distance Elements.

Activate the **IN_BF_ST_52b** (**Contact Position Breaker Failure Start** input) input without activating the **IN_3POL_AND** (**Three Open Pole**) input or the **IN_52bA**, **IN_52bB**, **IN_52bC** inputs (simultaneously). Verify that **Breaker Failure** and **Memorized Breaker Failure** flags are activated at 0.5 s.

Deactivate the **IN_BF_ST_52b** input and verify that, although the **Breaker Failure** signal resets, the **Memorized Breaker Failure** output does not reset until the **Memorized Breaker Failure Reset** signal is activated.

Apply a current of 3 A to phase C and activate the **IN_BF_ST_N** (**Ground Element Breaker Failure Start**) input. Verify that **Breaker Failure** and **Memorized Breaker Failure** flags are activated at 0.5 s.

Disconnect the current and verify that, although the **Breaker Failure** signal resets, the **Memorized Breaker Failure** output does not reset until the **Memorized Breaker Failure Reset** signal is activated.

3.15.8.d Internal Arc Detector

Since this is considered a complement to the Breaker Failure Element, the tests of this element are included in the same section

Consult the following indicators during the test: In the display on the **Information** - **Status** - **Measuring Elements** - **Breaker Failure** - **Internal Arc** menu, or on the status screen of the ***ZIVercomPlus***® (**Status** - **Elements** - **Breaker Failure** - **Internal Arc**).

Disable the Breaker Failure Element and enable that of Internal Arc detection. Adjust the pickup to 0.1 A and the timing to 0.5 s. Apply a current of 0.5 A to phase B and activate the **IN_52bB** input. Verify that the **Internal Arc Detector** flag is activated at 0.5 s.

3.16 Synchronism Unit

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3.16.1 Description

DLX-B models incorporate one Synchronism Check Element the function of which is to check whether the conditions at both ends of the supervised breaker are suitable to closing it (either by reclose or manual reset) and that there will be no oscillations.

The functioning of the synchronism unit is based, on one hand, on comparing the module, phase and/or frequency of the voltages on **Side A** (**Line**) and **Side B** (**Busbar**) to check if the two voltages are the same. On the other hand, the element can detect synchronism according to the energization on both sides of the breaker, that is, in terms of the possible combinations of presence/absence of voltage on sides A and B.

The voltage on **Side B** may correspond to phase A, B or C or phase-to-phase AB, BC or CA voltage as a function of the situation of the transformer on the busbar side. In order to compare said voltage with that of **Side A**, the **Side B Voltage** setting must be adequately configured. This setting will be used for angle compensation so that voltage on **Side B** may be compensated, as far as angle is concerned, through voltage on **Side A**.

In case phase-to-phase voltage is used on **Side B** for synchronism check, model compensation is required besides angle compensation, in order to compare voltages on both sides. To this end, **Side B Voltage Compensation Factor** (**K_{LB}**) setting must be set properly. As for magnitudes, the measured values are standardized, considering line-to-neutral voltages on both sides. As for angles, they are compensated according to the values shown in table 3.16-1. Magnitude standardization and angle compensation is made through the following settings:

- **Voltage on Side B**: through this setting, the measured value of the voltage on **side B** of the breaker is selected and the angle compensation to be used established. This setting is not considered for magnitude standardization.
- **Side B Voltage Compensation Factor B** (**K_{LB}**): based on the rated voltage on **Side A**, the rated voltage on **side B** is compensated through multiplication by parameter **K_{LB}** for standardization so that voltage difference criterion may be used for synchronism. Parameter **K_{LB}** is calculated as:

$$K_{LB} = \frac{V_{nominal\,SIDE\_A}}{V_{nominal\,SIDE\_B}}$$

The Synchronism Unit also takes into account the system's phase sequence (ABC or ACB). Appropriate angle compensation depends on **Phase sequence** (ABC / ACB) setting.

For example, if the voltage of side A is **A Phase** voltage and the voltage of side B is **B Phase** voltage, angle compensation for ABC sequence systems will be 120º; if system sequence is ACB, compensation will be 240º.

Table 3.16-1 lists all angle compensation possibilities:

Table 3.16-1: Angle Compensation (Phase Sequence)			
Side A	**Side B voltage setting**	**ABC Sequence**	**ACB Sequence**
V_A	V_A	0º	0º
V_A	V_B	120º	240º
V_A	V_C	240º	120º
V_A	V_{AB}	330º	30º
V_A	V_{BC}	90º	270º
V_A	V_{CA}	210º	150º

All angles measured with respect to V_A.

See the block diagram of the synchronism unit in figure 3.16.1.

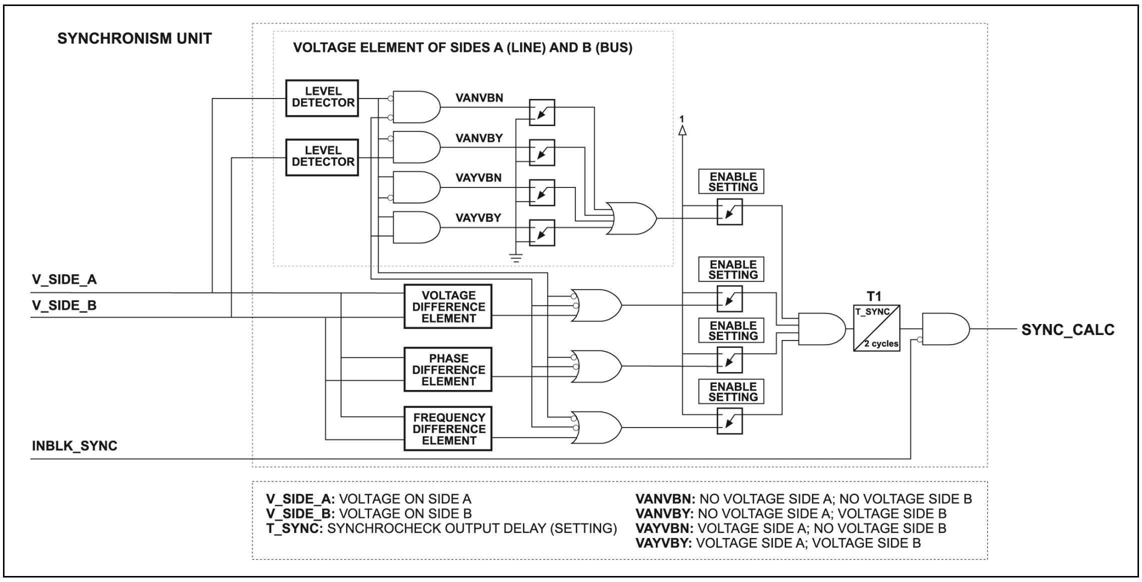

Figure 3.16.1 Block Diagram of the Synchronism Unit.

Note: the diagram shows that, if a permission value is 0 (element disabled), the input of the AND gate corresponding to this element will be at 1 as if this element were picked up. Therefore, if all the elements are disabled, the synchronism unit will be activated (unless it is blocked externally).

If the bay overvoltage element and/or the bus overvoltage element are reset, the inputs to the AND gate corresponding to the voltage difference, angle difference and frequency difference elements are always at 1.

The Synchronism Unit output (**SYNC_CALC**) can be blocked with the **Block Synchronism Check** (**INBLK_SYNC**) digital input.

The Synchronism Unit is comprised of four elements (voltage elements of sides A and B, voltage, phase and frequency difference elements). Each has a permission (**Enable**) setting. Details of its operation are explained next.

3.16.2 Voltage Difference Element

This element picks up when the voltage difference between the signals of sides A and B is less than or equal to the set value (in percentage), and resets when the ratio between the voltages of sides A and B is equal to or greater than 105% of the set value.

$$\text{(Startup value)} \left| \frac{\text{V sideA}}{\text{V sideB}} - 1 \right| \leq \text{setting}$$

$$\text{(Reset value)} \left| \frac{\text{V line}}{\text{V bus}} - 1 \right| \geq \text{setting} \times 1.05$$

3.16.3 Phase Difference Element

This element picks up when the phase displacement between the signals of sides A and B is less than or equal to the setting and resets when the phase displacement angle is greater than 105% of the set value or greater than the set value +2º.

If the **Breaker Closing Time Compensation** is set to **YES**, the Phase Difference element will consider the phase angle difference between side A y B voltages at the time of closing the breaker, taking into account its operating time through the **Breaker Closing Time** setting and the phase shift angle between sides A and B. Thus, the following phase difference will be added to the phase shift angle between side A and B voltages:

$$\frac{Tclosing(ms)}{1000} \cdot 360 \cdot \left(f_A - f_B\right)$$

where *Tclosing* is the breaker closing time, f_A is the frequency of side A voltage and f_B is the frequency of side B voltage.

In this way, if side A voltage rotates faster than side B ($f_A>f_B$), the above phase shift will be positive, whereas if side A voltage rotates slower than side B ($f_A<f_B$) the phase angle correction to take into account will be negative.

3.16.4 Frequency Difference Element

This element picks up when the frequency difference between the signals of sides A and B is less than the pickup (100% of the setting), and resets when this difference is greater than the setting + 0.01 Hz.

A and **B Side** signal angles are already compensated values according to table 3.16.1.

3.16.5 Voltage Element of Sides A and B

This element is comprised of two overvoltage elements (for **sides A** and **B** respectively). Each overvoltage element picks up when the RMS value of the input voltage exceeds 105% of the pickup value (set value) and resets when it is below 100% of this value. The voltages used are values standardized as line-to-neutral voltages.

The voltage element of **sides A** and **B** has two outputs that indicate the presence of voltage on each of the sides.

These outputs are generated whether they have been selected or not with the **Energization** setting, whose only function is to set the combinations to detect synchronism.

3.16.6 Selection of Type of Synchronism

The Recloser as well as the Command Logic (for closing operations of the breaker) uses the **SYNC_R** signal, which indicates the presence or absence of synchronism prior to resetting the breaker.

This information can be supplied to the **DLX** by the output of the IED's own Synchronism Unit (**SYNC_CALC** signal) or by the digital input of **External Synchronism** (**IN_SYNC_EXT** signal). The setting that determines the origin of the synchronization signal is the **Type of Synchronism** (**SEL_SYNC**).

The activation of the **Blocking Due to Fuse Failure** (**BLK_FF**) signal can cancel the **SYNC_R** signal if the **Synchronism Blocking Due to Fuse Failure** setting (**BLK_SYNC_FF**) is set to **YES**. Thus, closures which could occur without conditions of synchronism are avoided, since the fuse failure would generate a dead-line condition, which could automatically activate the **SYNC_R** signal (if the synchronism is external as well as if calculated) according to the **Energization** setting. The logic diagram which defines the synchronism signal (**SYNC_R**) is shown in Figure 3.16.2.

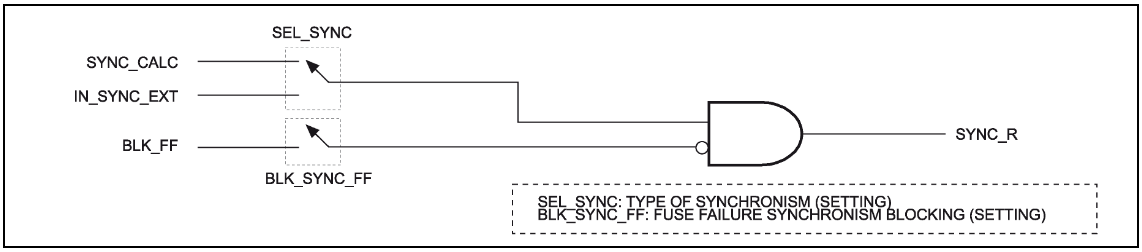

Figure 3.16.2 Block Diagram to Obtain the Synchronism Signal.

3.16.7 Application of the Synchronism Function

The synchronism function is used to monitor the connection of the two parts of the circuit by the reset of a breaker. It verifies that the voltages on both sides of the breaker ($V_{SIDE\ A}$ and $V_{SIDE\ B}$) are within the magnitude, angle and frequency limits established in the settings.

Verification of synchronism is defined as the comparison of the voltage difference of two circuits with different sources to be joined through an impedance (transmission line, feeder, etc.), or connected with parallel circuits of defined impedances. The voltages on both sides of a breaker are compared before executing its reset so as to minimize possible internal damage due to the voltage difference in phase, as well as magnitude and angle. This is very important in steam-powered power plants where the reclosings of the output lines with considerable angle differences can cause very serious damage to the shaft of the turbine.

The difference in voltage level and phase angle at a given point in time is the result of the load existing between remote sources connected through parallel circuits (load flow). It is also a consequence of the impedance of the elements that join them (even when there is no load flow in the parallel circuits or because the sources to connect to each other are totally independent and isolated from each other).

In meshed systems, the angle difference between two ends of an open breaker is not normally significant since their sources are joined remotely by other elements (equivalent or parallel circuits). Nevertheless, in isolated circuits, as in the case of an independent generator, the angle difference, the voltage levels and the relative phase shift of the voltage phasors can be very considerable. The relative phase shift of their voltages can even be very small or null in such a way that they will be in phase very infrequently. Due to the changing conditions of an electricity system (connection-disconnection of loads, sources and new inductive-capacitive elements) the relative phase shift of one phasor in respect of the other is not null, making synchronization necessary.

In the first case, although the length of the line whose ends (sources) will be connected to determine the angle difference between them should be considered, this is not sufficient to set the synchronism conditions before closing the breaker. Experience indicates that the angle difference window between voltage phasors must be set to 15º-20º.

3.16.8 Synchronism Unit Settings

Synchronism Unit			
Setting	**Range**	**Step**	**By default**
Enable	YES / NO		NO
Synchronism Type	0: External 1: Internal (Calculated)		0: External
Side B Voltage (Busbars)	V_A / V_B / V_C / V_{AB} / V_{BC} / V_{CA}		V_A
Side B Voltage Compensation Factor (K_{LB})	0.1 - 4	0.01	1
Fuse Failure Synchronism Blocking	YES / NO		NO
Breaker Closing Time Compensation	YES / NO		NO
Breaker Closing Time	5 - 1000 ms	5 ms	100 ms
Synchronism Output Time Delay	0.00 - 300 s	0.01 s	0 s
Voltage Supervision Elements Enable	YES / NO		NO
Side A Voltage Elements Pickup	20 - 200 V	1 V	20 V
Side B Voltage Elements Pickup	20 - 200 V	1 V	20 V
Energization Mask No Voltage Side A, No Voltage Side B No Voltage Side A, Voltage Side B Voltage Side A, No Voltage Side B Voltage Side A, Voltage Side B	 YES / NO YES / NO YES / NO YES / NO		 NO YES NO YES
Voltage Difference Element Enable	YES / NO		NO
Maximum Voltage Difference	2% - 30%	1%	2%
Phase Difference Element Enable	YES / NO		NO
Maximum Phase Difference	2 - 80º	1º	2º
Frequency Difference Element Enable	YES / NO		NO
Maximum Frequency Difference	0.005 - 2.00Hz	0.01 Hz	0.01 Hz

- **Synchronism Unit: MMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	4 - OVERCURRENT
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - LINE DIFFERENTIAL	**0 - SYNC ENABLE**
1 - FUSE FAILURE	**1 - TYPE OF SYNC**
2 - DEAD LINE DETECTOR	**2 - BUSBAR SELECTION**
...	**3 - BUS VOLT. COMPENS.**
9 - SYNCROCHECK	**4 - VOLTAGE SUPRV ENBL**
...	**5 - SIDE A VOLT. PU**
	6 - SIDE B VOLT. PU
	7 - ENERGIZATION MASK
	8 - VOLT. DIFF. ENABLE
	9 - MAX. VOLTAGE DIFF.
	10 - PHASE DIFF. ENABLE
	11 - MAX. PHASE DIFF.
	12 - FREQ. DIFF. ENABLE
	13 - MAX. FREQ. DIFF.
	14 - SYNC DELAY
	15 - FF SYNC. BLOCK
	16 - BRK CLOSE T COMP
	17 - BRK CLOSE T

3.16.9 Digital Inputs and Events of the Synchronism Module

Table 3.16-2: Digital Inputs and Events of the Synchronism Module		
Name	**Description**	**Function**
INBLK_SYNC	Close Synchronism Block Input	Activation of the input blocks the activation of the synchronism unit output (calculated synchronism).
ENBL_SYNC	Close Synchronism Enable Input	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”
IN_SYNC_EXT	External Synchronism Input	Activation of the input is necessary to permit the recloser to generate a close command if the supervision by synchronism setting is enabled and the synchronism mode chosen is “external.”

3.16.10 Digital Outputs and Events of the Synchronism Module

Table 3.16-3: Digital Outputs and Events of the Synchronism Module		
Name	**Description**	**Function**
SYNC_CALC	Synchronism Unit Activation	The synchronism unit determines that there are overall close conditions.
P_SYNC_DPH	Permission to Close by Phase Difference	The synchronism unit determines that there are close conditions by the phase difference criterion.
P_SYNC_DF	Permission to Close by Frequency Difference	The synchronism unit determines that there are close conditions by the frequency difference criterion.
P_SYNC_DV	Permission to Close by Voltage Difference	The synchronism unit determines that there are close conditions by the voltage difference criterion.
P_SYNC_EL	Permission to Close by Energization On The Sides	The synchronism unit determines that there are close conditions by the criterion of presence/absence of voltages on sides A and B.

Table 3.16-3: Digital Outputs and Events of the Synchronism Module

Name	Description	Function
SYNC_R	Close by Synchronism Enabled	It is the signal that the recloser receives to monitor the close by synchronism. Its activation indicates that there is permission, and depending on how the selector is set, it will be external or calculated synchronism.
SYNC_ENBLD	Close Synchronism Enabled	Indication of enabled or disabled status of the unit.
V_SIDE_A	Voltage on Side A	It indicates presence of voltage on side A.
V_SIDE_B	Voltage on Side B	It indicates presence of voltage on side B.
INBLK_SYNC	Close Synchronism Block Input	The same as for the Digital Input.
ENBL_SYNC	Close Synchronism Enable Input	The same as for the Digital Input.
IN_SYNC_EXT	External Synchronism Input	The same as for the Digital Input.

CAUTION!

If, while the Permission (Enable) setting is YES, the four bits of the energization mask are set to NO, the voltage element is deactivated and, consequently, the synchronism unit. Therefore, if you want to disable the voltage element of sides A and B, set that element's Permission to NO and not the four bits of the energization mask.

3.16.11 Synchronism Unit Test

To verify this unit, first the protection units are disabled. Then, the system is prepared to measure the time between the injection of the voltage and the activation of the Synchronism Unit. Lastly, the signals indicated in Table 3.16-4 are checked.

Table 3.16-4:Output Configuration

Logic Signal	Description of Logic Signal
SINC_CALC	Activation of the synchronism unit
Side A Voltage	Voltage on side A detected
Side B Voltage	Voltage on side B detected

3.16.11.a Voltage Elements Test

Disable the Voltage Difference, Phase Difference and Frequency Difference elements. The Synchronism Unit is set as follows:

Synchronism Enable	**YES**
Type of Synchronism	**1: Internal**
Side B Voltage	**1: V_B**
Fuse Failure Synchronism Blocking	**NO**
Side B Voltage Compensation Factor (K_{LB})	**1**

- **Voltage Supervision Element**

Enable	**YES**
Side A Detection Pickup	**25 V**
Side B Detection Pickup	**25 V**
Energization Masks	
No Voltage Side A; No Voltage Side B	**NO**
No Voltage Side A; Voltage Side B	**YES**
Voltage Side A; No Voltage Side B	**YES**
Voltage Side A; Voltage Side B	**NO**

- **Voltage Difference Element**

Enable	**YES**
Maximum Voltage Difference	**10%**

- **Phase Difference Element**

Enable	**YES**
Maximum Phase Difference	**20º**

- **Frequency Difference Element**

Enable	**YES / NO**
Maximum Frequency Difference	**0.20 Hz**
Synchronism Output Time Delay	**0.00s**

- **Pickups**

Three tests should be performed for each of the three different pickup settings.

Apply a voltage of 15 Vac with a phase angle of 0º to phase A, and apply 65 Vac with a phase angle of 0º to voltage Side B (Bus Voltage). Synchronism Unit should activate.

Increase the voltage of phase A until the synchronism unit is deactivated. The voltage at which it is deactivated should be within the ranges shown in Table 3.16-5 for the corresponding pickup setting.

Table 3.16-5: Pickup and Reset of the Voltage Units

Pickup Setting (V)	Pickup Value (V)		Dropout Value (V)	
	Minimum	Maximum	Minimum	Maximum
25	24.25	25.75	23.04	24.46
45	43.65	46.35	41.47	44.03
60	58.20	61.80	55.29	58.71

The dropout should take place instantaneously within the ranges shown in Table 3.16-5, corresponding to the setting used.

3.16.11.b Voltage Difference Element Test

Enable the Voltage Difference Element, and disable the Voltage, Phase Difference and Frequency Difference elements.

- **Pickup**

Three tests should be performed for each of the three different pickup settings.

A voltage of 30 Vac and phase 0º is applied to phase A and of 65 Vac and phase 0º to the voltage channel of side B. All the outputs must deactivate.

Increase the voltage of phase A until Synchronism element is activated and stable. The voltage where this activation occurs should be within the ranges shown in Table 3.16-6 for the corresponding pickup setting.

The dropout should take place instantaneously within the ranges shown in Table 3.16-6, corresponding to the setting used.

Table 3.16-6: Pickup and Reset of The Voltage Difference Unit

Pickup Setting (p.u.)	Pickup Value (V)		Dropout Value (V)	
	Minimum	Maximum	Minimum	Maximum
10%	56.75	60.26	56.42	59.92
20%	50.44	53.56	49.81	52.89
30%	44.14	46.87	43.19	45.87

3.16.11.c Phase Difference Element Test

Enable the Phase Difference Element, and disable the Voltage, Voltage Difference and Frequency Difference Elements.

- **Pickup**

Three tests should be performed for each of the three different pickup settings.

Apply a voltage of 65 Vac with a phase angle of 50º to phase A, and apply 65 Vac with a phase angle of 0º to the voltage side B (bus voltage).

Reduce the angle of the voltage of phase A, until Synchronism Element is activated and stable. The angle where this activation occurs should be within the ranges shown in Table 3.16-7 for the corresponding pickup setting.

The dropout should take place instantaneously within the ranges shown in Table 3.16-7, corresponding to the setting used.

Table 3.16-7: Pickup and Reset of The Phase Difference Unit

Pickup Setting (º)	**Pickup Value (º)**		**Dropout Value (º)**	
	Minimum	Maximum	Minimum	Maximum
20	19	21	21	23
30	29	31	31	33
40	39	41	41	43

- **Breaker Closing Time Compensation**

Set the Phase Angle Difference element to 20º. Set to YES the **Breaker Closing Time Compensation Enable** setting. Set the **Breaker Closing Time** to 50 ms.

Inject VA=65 $_{0º}$ and VSINC=65 $_{30º}$, both at 50 Hz. Change VSINC voltage frequency to 51 Hz. Given the frequency difference between the voltages at both sides of the breaker, during its closing time, voltage VSINC, rotating faster than voltage VA, will have a shift of 18º

$$\frac{Tclosing(ms)}{1000} \cdot 360 \cdot \left(f_A - f_B\right)$$

Where $T_{closing}$ is breaker closing time, f_A is VA frequency and f_B is VB frequency). Thus, check that the phase difference element picks up when VSINC lags 37º to 39º relative to VA and resets when VSINC leads 1º to 3º relative to VA.

3.16.11.d Frequency Difference Element Test

Enable the Frequency Difference Element and disable the remaining elements.

- **Pickup**

Three tests should be performed for each of the pickup settings indicated in Table 3.16-8.

Apply a voltage of 65 Vac with a phase angle of 0º and a frequency of 53 Hz to phase A, and apply 65 Vac with a phase angle of 0º and a frequency of 50 Hz to voltage side B (bus voltage). All the outputs must deactivate.

Reduce the frequency of the voltage to phase A until Synchronism element is active and stable. The frequency where this occurs should be within the ranges shown in Table 3.16-8for the corresponding pickup setting. The dropout should take place instantaneously within the ranges shown in Table 3.16-8, corresponding to the setting used.

Table 3.16-8: Pickup and Reset of the Frequency Difference Unit

Pickup Setting (Hz)	Pickup Difference (Hz)		Dropout Difference (Hz)	
	Minimum	Maximum	Minimum	Maximum
0.20	0.19	0.21	0.20	0.22
1.00	0.97	1.03	0.98	1.04
2.00	1.94	2.06	1.95	2.07

3.16.11.e Time Settings Test

Three tests should be performed for three different pickup settings (0.10s, 1s and 10s).

Prepare the system to measure the time between the application of voltage and the close of the contact of the Synchronism element.

Only the voltage difference unit is enabled between **sides A** and **B**.

A voltage of 65 V and 0º is applied to phase A and to the voltage channel of side B. The synchronism unit must activate within the margin of ±1% of the setting or ±20ms.

The angle to add to the phase displacement between VA and VSINC is -1.8 º. Verify that the pickup of this element is at an angle of VSINC of 356.8 º.

3.17 Pole Discordance Detector

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3.17.4 Digital Outputs and Events of the Pole Discordance Detector 3.17-4
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3.17.1 Operating Principles

This unit is for the purpose of detecting a discordance in the position of the three breaker poles. If this condition is maintained during the **T_PD** (**Discordance Time**) time setting, the **TRIP_PD** (**Pole Discordance Detector Trip**) trip signal is generated. Given that the single-phase reclose cycles will produce a pole discordance condition, the **T_PD** time setting should be longer than the single-phase reclose time.

Figure 3.17.1 shows the operation diagram of the Pole Discordance Detector.

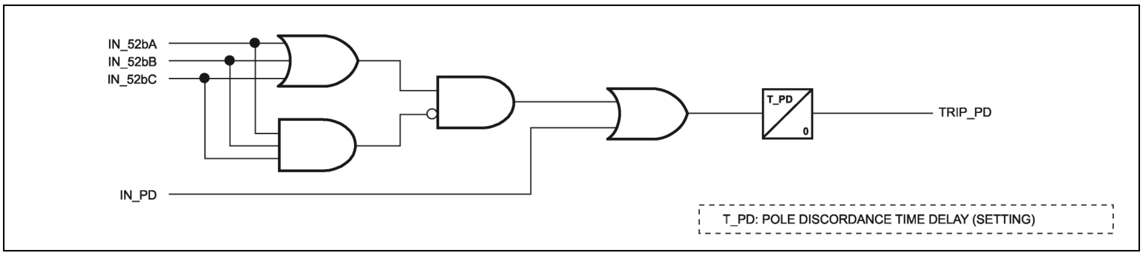

Figure 3.17.1 Diagram of the Pole Discordance Detector.

It will be possible to detect the existence of pole discordance from the status of the three digital inputs associated with the status of the three poles of the breaker (activated if the corresponding pole is open). Notwithstanding, many breakers incorporate a wiring logic in their control cabinets, which detects the pole discordance (based on the status of the **52aA/B/C** and **52bA/B/C** contacts), generating a signal in this case. For this reason, the **DLX** IED incorporates a digital input, **IN_PD**, to receive this signal, which will directly activate the **TRIP_PD** output.

3.17.2 Pole Discordance Detector Settings

Pole Discordance Detector			
Setting	**Range**	**Step**	**By default**
Enable	YES / NO		NO
Poles Discordance Time Delay	0 - 50 s	0.01 s	2 s

- **Pole Discordance Detector: HMI Access (DLX-A Model)**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - OPEN POLE LOGIC
2 - ACTIVATE GROUP	2 - RECLOSER	2 - OVERCURRENT
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN PHASE DETECTOR
4 - INFORMATION	...	4 - CT SUPERVISION
		5 - THERMAL IMAGE
		6 - COLD LOAD
		7 - BREAKER FAILURE
		8 - POLE DISCREPANCY
		9 - PHASE SELECTOR
		10 - PROTECTION LOGIC

0 - LINE DIFFERENTIAL	
1 - OPEN POLE LOGIC	
2 - OVERCURRENT	
...	**0 - POLE DISCR ENABLE**
8 - POLE DISCREPANCY	**1 - POLE DISCREP. DELAY**
...	

- **Pole Discordance Detector: HMI Access (DLX-B Model)**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	4 - OVERCURRENT
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - DIFERENCIAL LINEA	
1 - FALLO FUSIBLE	
2 - DET. LINEA MUERTA	
...	**0 - POLE DISCR ENABLE**
14 - DISCORDANCIA POLOS	**1 - POLE DISCREP. DELAY**
...	

3.17.3 Digital Inputs and Events of the Pole Discordance Detector

Table 3.17-1: Digital Inputs and Events of the Pole Discordance Detector		
Name	**Description**	**Function**
ENBL_PD	Pole Discordance Detector Enable Input	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”
IN_52bA	Open A Pole Position Input	Activation of this input indicates that the 52b contact of A pole position of the breaker is closed.
IN_52bB	Open B Pole Position Input	Activation of this input indicates that the 52b contact of B pole position of the breaker is closed.
IN_52bC	Open C Pole Position Input	Activation of this input indicates that the 52b contact of C pole position of the breaker is closed.
IN_PD	Pole Discordance Detector Input	Activation of this input directly generates the startup of the timer associated with the pole discordance detector.

3.17.4 Digital Outputs and Events of the Pole Discordance Detector

Table 3.17-2: Digital Outputs and Events of the Pole Discordance Detector		
Name	**Description**	**Function**
TRIP_PD	Pole Discordance Detector Trip	Trip of the unit.
PD_ENBLD	Pole Discordance Detector Enabled	Indication of enabled or disabled status of the unit.
ENBL_PD	Pole Discordance Detector Enable Input	The same as for the Digital Input.
IN_52bA	Open A Pole Position Input	The same as for the Digital Input.
IN_52bB	Open B Pole Position Input	The same as for the Digital Input.
IN_52bC	Open C Pole Position Input	The same as for the Digital Input.
IN_PD	Pole Discordance Detector Input	The same as for the Digital Input.

3.17.5 Pole Discordance Detector Test

The following indicators will be monitored during the test:

In the display on the **Information** - **Status** - **Measuring elements** - **Pole Discordance** screen, or on the status screen of the ***ZIVercomPlus***® (**Status** - **Elements** - **Pole Discordance**).

The Pole Discordance Element will be enabled and the remaining elements disabled.

Adjust the timing to 10 s.

Activate the **Open A Pole Position** input, without the **Open B Pole Position** and **Open C Pole Position** inputs being active. Verify that a three-phase trip due to pole discordance is produced after 10 s.

Repeat the test with the **Open A Pole Position** and **Open B Pole Position** inputs active without the **Open C Pole Position** input active. Verify that a three-phase trip due to pole discordance is produced after 10 s.

Activate the **Pole Discordance** input and verify that a three-phase trip due to pole discordance is produced after 10 s.

3.18 Current Measurement Supervision

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3.18.1 Introduction

All models count on a supervision system for the set of elements that make up the phase current measurement system, from external current transformers, to copper cables that connect them to the relay, up to the internal magnetic modules on the **DLX** relay itself.

3.18.2 Operation Principles

This supervision function is exclusively based on the measurement of phase currents. Measurement of the **three** phase currents is required for its application, otherwise it must be disabled.

Due to the unlikely simultaneous failure of more than one phase, a simple algorithm is used to enable the detection of failures in a single phase each time. Simultaneous failures are not detected.

When a phase current (phase **X**) below 2% of its rated value is detected, other phase currents are checked (phases **Y** and **Z**) to see if they exceed 5% and are below 120% of their rated value. The angular difference between these currents is also calculated, which, under normal operating conditions, must be within the 120º±10º range.

If “normal” operating conditions are detected in phases **Y** and **Z**, the phase **X** current circuit failure alarm is activated.

Figure 3.18.1 shows the supervision algorithm used for current measurement in phase A.

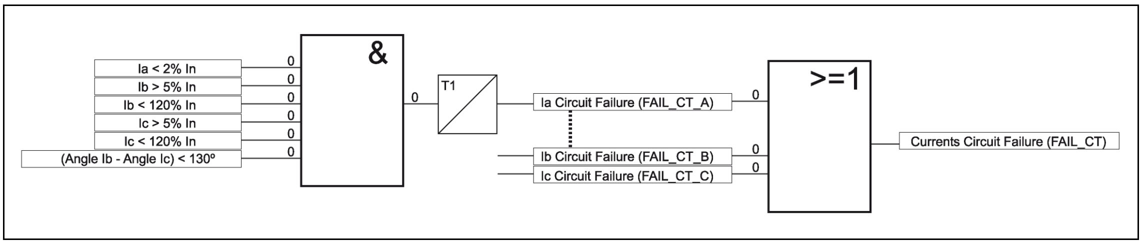

Figure 3.18.1 Supervision Algorithm for Current Measurement in Phase A.

Failure detection in any of the measuring circuits only generates the activation of the following signals: **FAIL_CT_A**, **FAIL_CT_B**, **FAIL_CT_C** and **FAIL_CT**. Blocking the operation of protection elements that are affected by measurement unbalance of phase currents must be programmed in ***ZIVerComPlus***® logic.

3.18.3 Current Measurement Supervision Settings

Current Measurement Supervision			
Setting	**Range**	**Step**	**By Default**
CT Supervision Enable	YES / NO		NO
CT Supervision Time	0.15 - 300 s		0.5 s

- **Current Measurement Supervision: HMI Access (DLX-A Model)**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - OPEN POLE LOGIC
2 - ACTIVATE GROUP	2 - RECLOSER	2 - OVERCURRENT
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN PHASE DETECTOR
4 - INFORMATION	...	**4 - CT SUPERVISION**
		5 - THERMAL IMAGE
		6 - COLD LOAD
		7 - BREAKER FAILURE
		8 - POLE DISCREPANCY
		9 - PHASE SELECTOR
		10 - PROTECTION LOGIC

0 - LINE DIFFERENTIAL	
1 - OPEN POLE LOGIC	
2 - OVERCURRENT	
3 - OPEN PHASE DETECTOR	**0 - CT SUPERV ENABLE**
4 - CT SUPERVISION	**1 - CT SUPERV TIME**
...	

- **Current Measurement Supervision: HMI Access (DLX-B Model)**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	4 - OVERCURRENT
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - LINE DIFFERENTIAL	
1 - FUSE FAILURE	
2 - DEAD LINE DETECTOR	
...	**0 - CT SUPERV ENABLE**
8 - CT SUPERVISION	**1 - CT SUPERV TIME**
...	

3.18.4 Digital Inputs of Current Measurement Supervision Module

Table 3.18-1: Digital Inputs of the Current Measurement Supervision Module		
Name	**Description**	**Function**
IN_ENBL_SUPCT	CT Supervision Enable Input	Activation of this input brings the element into operation. It can be assigned to a digital input by level or to a command from the communications protocol, or from the HMI: The default value for this logic input is “1”.
IN_BLK_SUPCT	CT Supervision Block Input	Activation of this input generates the blocking of the supervision.

3.18.5 Auxiliary Outputs and Events of the Current Measurement Supervision Module

Table 3.18-2: Auxiliary Outputs and Events of the Current Measurement Supervision Module		
Name	**Description**	**Function**
FAIL_CT_A	Activation of CT Supervision Element for Phase A	Its activation indicates the existence of a failure in the measuring system of one of the phases
FAIL_CT_B	Activation of CT Supervision Element for Phase B	
FAIL_CT_C	Activation of CT Supervision Element for Phase C	
FAIL_CT	Activation of CT Supervision Element	
ENBL_SUPCT	Activation of CT Supervision Enabled	Block output due to condition of fuse failure detected by the element in question.
EB_SUPCT	Activation of CT Supervision Block Input	Block output due to condition of fuse failure (either detected by the element itself, or else by digital input).

3.19 Single / Three-Phase Tripping Logic

3.19.1	Single / Three-Phase Tripping Logic. DLX-B Models	3.19-2
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3.19.1 Single / Three-Phase Tripping Logic. DLX-B Models

DLX-B terminal units are provided with a Single- or Three-Phase Tripping Logic. Trip commands are generated for phase A, B, and C according to activation of protection elements, blocking status contact inputs, element masks, recloser status, etc. The Tripping Logic comprises the following sub-logics:

1. **Trip Command Generation Logic**, in charge of processing the activation of the different protection elements responsible for trips to generate a general trip command.
2. **Three-Phase Trip Logic**, in charge of indicating to the phase trip logic if the trip must be a three-phase trip.
3. **Phase Trip Logic**, in charge of generating independent tripping signals for phases A, B, and C (outputs **TRIP_A**, **TRIP_B** and **TRIP_C**), which will be used by the command module (see 3.21) to generate the open outputs of each pole.

The block diagram of Figure 3.19.8 shows the complete Single / Three-Phase Tripping Logic.

3.19.2 Trip Logic. Models DLX-A Models

The **DLX-A** IEDs are provided with a tripping logic which generates a breaker trip signal according to the activation of the protection units, blocking digital inputs, actuation masks of the units, recloser status, etc. Consequently, it is in charge of the trip generation. The Tripping Logic comprises the following sub-logics:

1. **Trip Command Generation Logic**, in charge of processing the activation of the different protection elements responsible for trips to generate a general trip command.
2. **Three-Phase Trip Logic**, in charge of generating the tripping output, which will be used by the command module to generate the open command.

3.19.3 Trip Command Generation Logic

This logic generates a trip command according to activation of the protection elements. The settings to enable or the elements involved are (depending on model):

Differential Units (Phase, Ground and Sensitive Ground).
Overcurrent Protection Schemes.
Auxiliary Units:
Phase Instantaneous Overcurrent Elements
Ground Instantaneous Overcurrent Elements
Sensitive Ground Instantaneous Overcurrent Elements
Negative Sequence Instantaneous Overcurrent Elements
Phase Time Overcurrent Elements
Ground Time Overcurrent Elements
Sensitive Ground Time Overcurrent Elements
Negative Sequence Time Overcurrent Elements
Thermal Image Protection
Open Phase Detector
Phase Undervoltage Elements
Phase Overvoltage Elements
Ground Overvoltage Elements
Underfrequency Elements
Overfrequency Elements
Rate of Change Elements
Pole Discordance Detector

Enabling the **Step Distance** scheme (signal **TRIP_STP**) activates the protection elements for ground fault and phase-to-phase faults in Zones 1, 2, 3, 4 and 5. The **Zone Trip Mask** setting (see 3.2.2 Step Distance) allows the user to independently enable or disable tripping by each of these elements.

Tripping either by Differential Elements or Auxiliary Elements may be masked via **Differential Element Masked Trip** and **Auxiliary Element Masked Trip** settings, which appear, in ***ZivercomPlus***®, within the **Protection Logic** menu. If an element of any of the above masks is set to **0** (**NO**), the trip will be masked or blocked.

Tripping by protection scheme (**TRIP_SCHM_OC**) cannot be masked, so if a breaker trip is not desired, said scheme must be disabled (**Type of Protection Scheme** set to **None**).

CAUTION!

Given that the setting of the Auxiliary Unit Mask allows inhibiting the trip by the auxiliary units (not differential units), if it is required that any of these produce a trip, it should be ensured that this setting has an unmasked measuring unit. Otherwise, the protection will be unable to trip units other than differentials.

As shown in Figures 3.19.8 and 3.19.9, the Trip Command will be generated if any of the following occurs:

1. A trip by Differential Unit (Phase, Ground o Negative Sequence).
2. A trip by an Overcurrent Protection Scheme (**TRIP_SCHM_OC**).
3. A trip of any of the auxiliary units.
4. Activation of **Programmable Trip** (**INPROGTRIP**).
5. The prior existence of a trip.

Moreover, the digital input **Trip Blocking** (**INBLK_TRIP**) must not be activated and **Fault Detector** (**FD**) must be activated provided **Supervision by Fault Detector** is set to YES and the trip is not caused by Sensitive Ground Overcurrent, Voltage, Frequency, Thermal Image, Pole Discordance, Weak Infeed Logic Elements or **Programmable Trip** input.

In **DLX** relays, it must also be taken into account that the activation of **Three-Phase Trip Preparation Block** input (**INBLK_3PHPREP)** will disable any three-phase-only trip (see conditions in following paragraph). Also, **Pole Trip Block** inputs (**INBLK_TRIP_A, INBLK_TRIP_B, INBLK_TRIP_C)** will disable the trip of the corresponding pole.

3.19.4 Three-Phase Trip Logic. DLX-B Models

The Three-Phase Trip Logic function detects if the trip generated by the previous logic will be a three-phase trip. In the case of a three-phase trip, the logic will generate the **Three-Phase Trip Ready** signal (**3PH_PREP**).

Whenever the detected fault is a fault between phases (two or three phases), the trip will be a three-phase trip. Also, there are a series of conditions where a three-phase trip will be generated independent of the fault detected. These conditions are:

1. The **Three-Phase Trip** setting is set to **YES**.
2. The status contact input **Three-Phase Trip Enable** is activated (signal **3POL_OPEN**).
3. If the Recloser is in **Blocking Command** (**RCLS_CMD_LO** signal activated) or in **Internal Blocking** (**RCLS_LO** signal activated).
4. The Recloser is set to three-phase mode (**3P Mode**).
5. The **Recloser Sequence** is activated (signal **RECLOSING**). (Therefore, a three-phase trip will always follow any reclosing operation.).
6. If the trip of Ground or Negative Sequence Differential units is produced and the **Single-Phase Trip 87G** (**1P_87G_ON**) setting is at **NO**.
7. If the trip of any of the auxiliary units is produced, except in case of unit 1 of Ground or Negative Sequence Overcurrent and the **Single-Phase Trip 67G** (**1P_67G_ON**) setting is at **YES** and the fault is single phase (**AG_F**, **BG_F** and **CG_F**).
8. If the **Programmable Trip** (**INPROGTRIP**) input has been activated.
9. If at least two breaker poles have tripped (**3PH_PREP_TRIP** signal).

No matter the above conditions, activating the **Three-phase Trip Preparation Block** input (**INBLK_3PHPREP)** disables all three-phase trip preparations.

Under any of the above conditions, the trip will be three-phase, even if a single-phase fault is detected. Consequently, single-phase trips can only occur when the following trip:

1. The Phase Differential Element and single phase fault (trip activation by single phase differential: **TRIP_87A** without **TRIP_87B** and **TRIP_87C**, etc).
2. Ground or Negative Sequence Differential units, provided that the **Single-Phase Trip 87G (1P_87G_ON**) setting is set at **YES** and the fault is single phase **(AG_F**, **BG_F** and **CG_F**).
3. **Unit 1** of **Ground** or **Negative Sequence Overcurrent** provided that the **Single-Phase Trip 67G** (**1P_67G_ON**) setting is set at **YES** and the fault is single phase (**AG**, **BG** and **CG**).
4. The overcurrent protection scheme is in operation, with the fault also being single phase (**AG_F**, **BG_F** and **CG_F** outputs or **TRIP_WI_I_A**, **TRIP_WI_I_B** and **TRIP_WI_I_C** outputs), provided this is carried out prior to the timing of unit 2 of ground or negative sequence overcurrent.
5. When ground or negative sequence overcurrent element 1 pickup or **Overreach Element Pickup** input is activated, provided it is a single-phase fault and **Three-phase Trip Preparation Block** input (**INBLK_3PHPREP)** activates or **pole trip block** inputs (**INBLK_TRIP_A, INBLK_TRIP_B, INBLK_TRIP_C)** associated to unfaulted phases activate**.** In this way, single-phase time delayed trips would be allowed.

All provided that the above-mentioned **Three-Phase Trip Ready** signal has not been activated.

3.19.5 Trip Logic Operation

3.19.5.a Phase Trip Logic. DLX-B Models

The phase trip logic function generates the independent trip command for each of the phases (signals **TRIP_A**, **TRIP_B** and **TRIP_C**), the **Trip** signal (**TRIP**) and the **Three-Phase Trip** signal (**TRIP_3PH**). To generate these signals, the logic uses the **Trip Command** signal and the **Three-Phase Trip Ready** signal (**3PH_PREP**), described in the previous sections.

The tripping logic of the poles is formed of three single-phase sub-logics corresponding to phases A, B and C. The trip command is common to the three logics. However, in case that three-phase trip conditions present themselves (for example, if the recloser is blocked), on activating the **3PH_PREP** signal, the trip is produced in the three phases even though the single-phase sub-logics indicate otherwise. On the other side, pole trips can be disabled by means of **INBLK_TRIP_A, INBLK_TRIP_B, INBLK_TRIP_C** inputs.

Once the trip generating units are deactivated, the trip contacts remain latched until:

1. The Fault Detector is deactivated (if the **Supervision by Fault Detector** setting is at **YES**) or the logic input signal **Trip Blocking** (**INBLK_TRIP**) is activated.
2. The applicable pole trip block input is activated.

3.19.5.b Tripping Logic of the Breaker. DLX-A Models

The function of this logic is to generate the **Direct Trip** (**TRIP**) output.

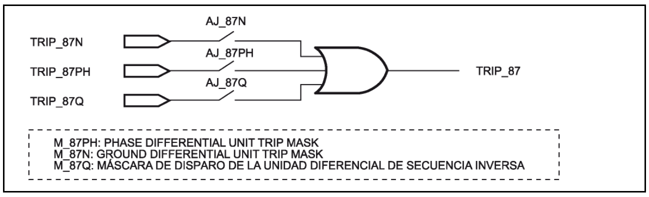

Figure 3.19.1 Activation Logic of Differential Units for Tripping Logic.

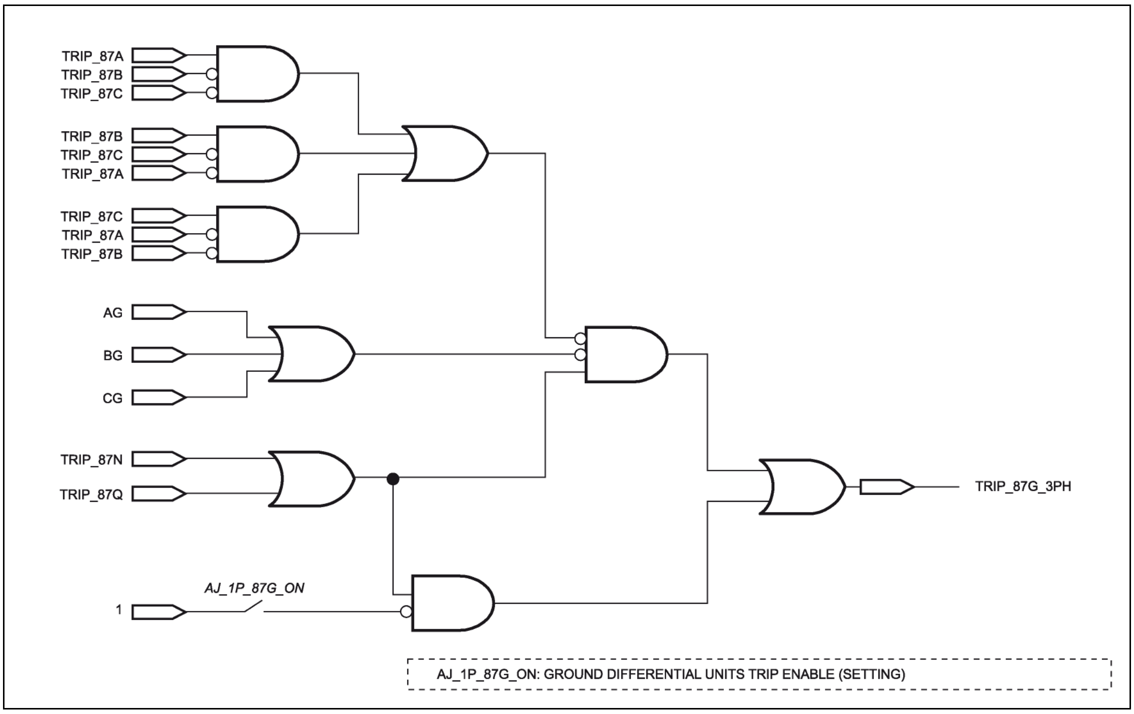

Figure 3.19.2 Activation Logic of Differential Units for Tripping Logic.

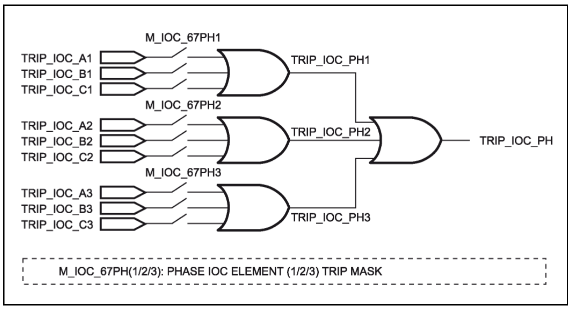

Figure 3.19.3 Activation Logic of Phase Instantaneous Overcurrent Units for Tripping Logic.

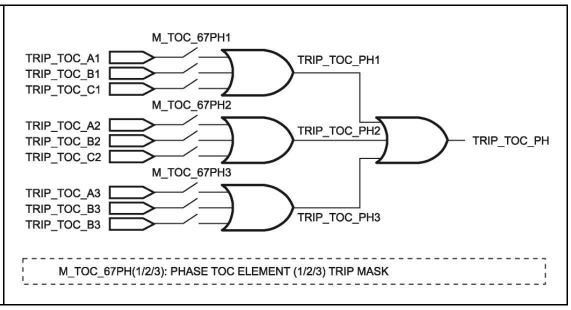

Figure 3.19.4 Activation Logic of Phase Time Overcurrent Units for Tripping Logic.

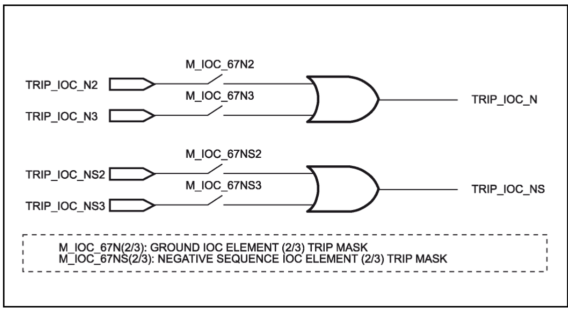

Figure 3.19.5 Activation Logic of Ground and Negative Sequence Instantaneous Overcurrent Units for Tripping Logic.

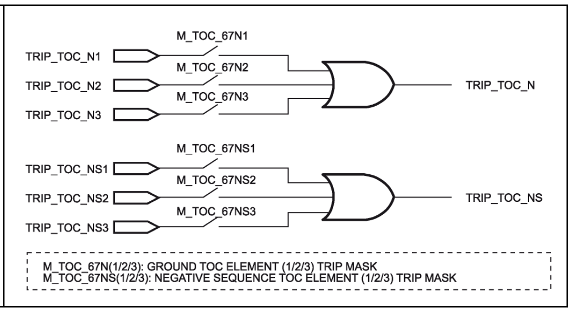

Figure 3.19.6 Activation Logic of Ground and Negative Sequence Time Overcurrent Units for Tripping Logic.

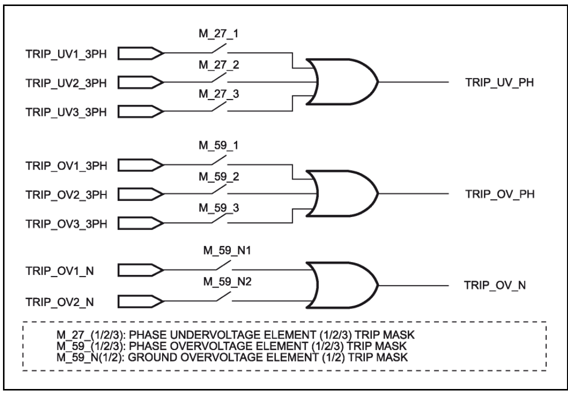

Figure 3.19.7 Activation Logic of Voltage Units for Tripping Logic.

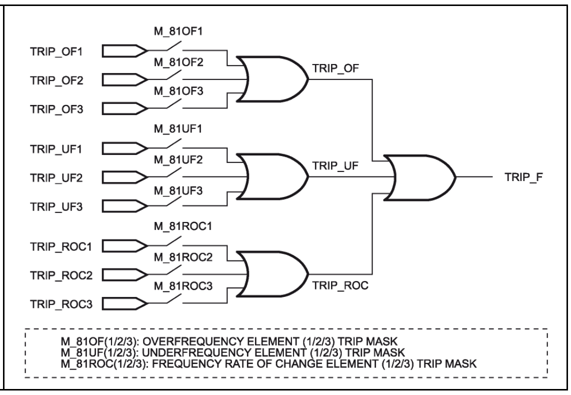

Figure 3.19.8 Activation Logic of Frequency Units for Tripping Logic.

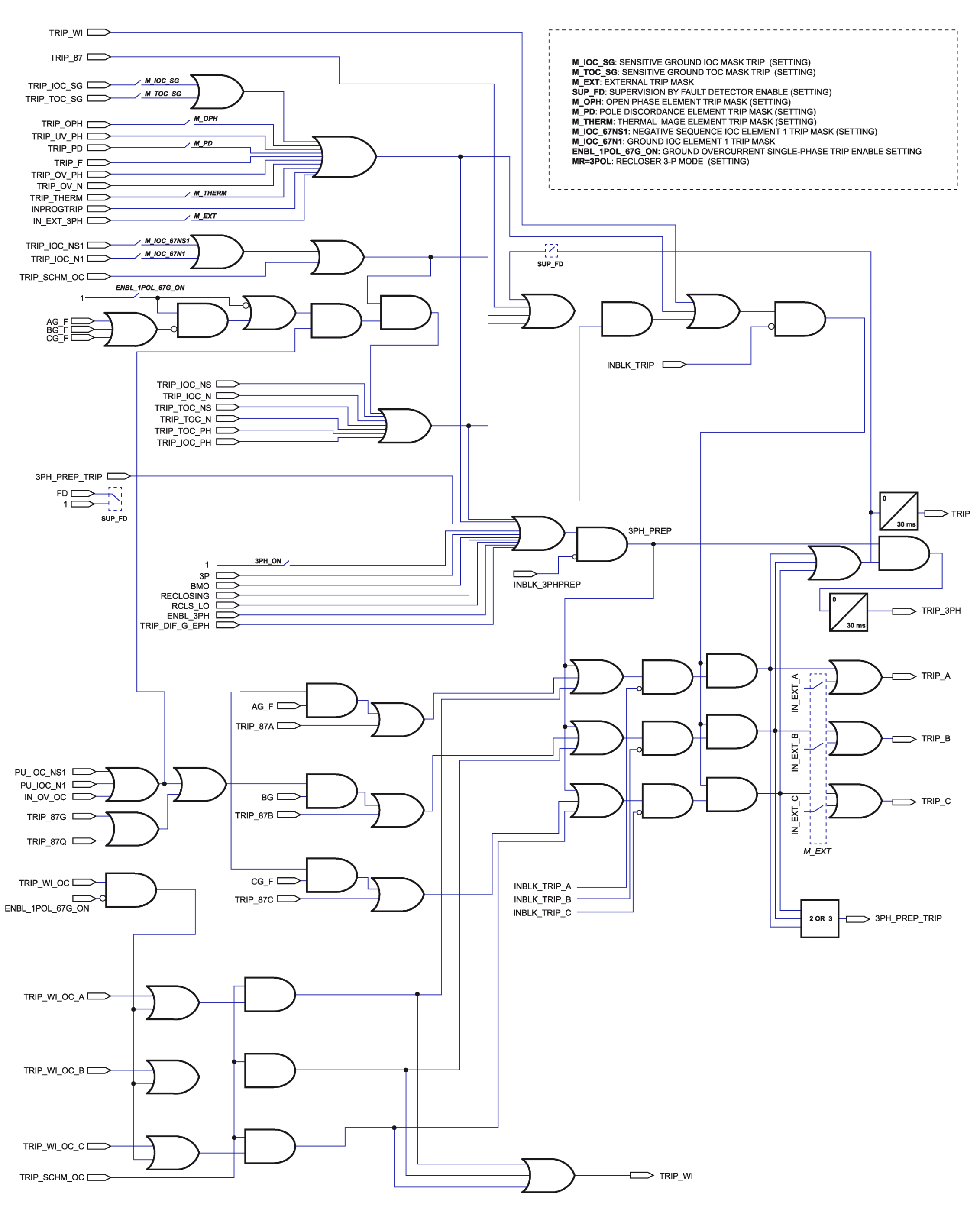

Figure 3.19.9 Block Diagram of the Single-Three-Phase Trip Logic (DLX-B Models).

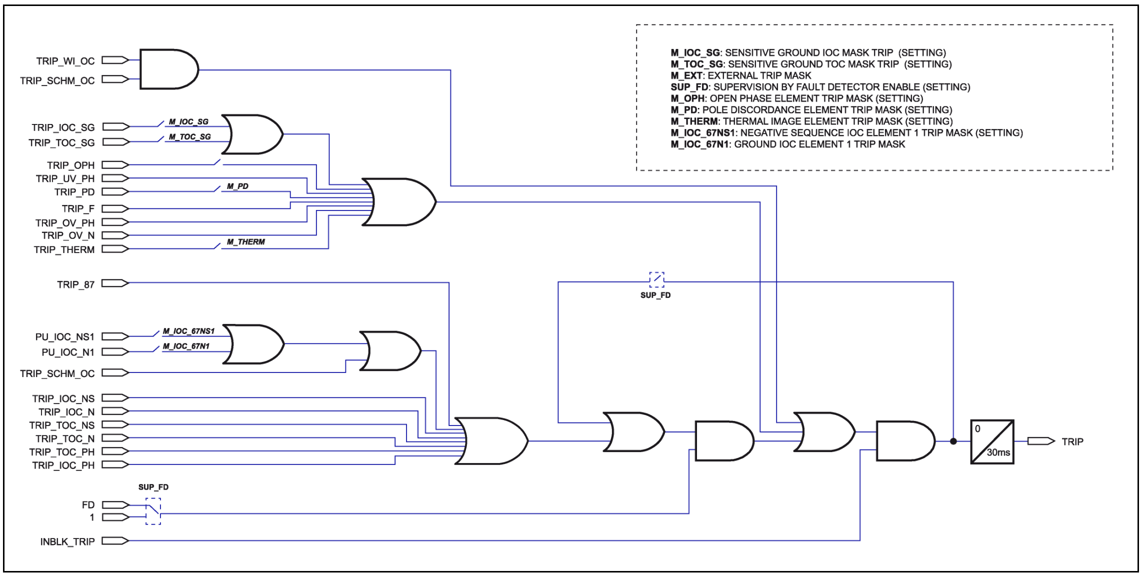

Figure 3.19.10 Block Diagram of the Tripping Logic (DLX-B Models).

3.19.6 Tripping Logic Settings

Tripping Logic			
Setting	**Range**	**Step**	**By default**
Three-Phase Trip (DLX-B)*	YES / NO		NO
Ground Differential Single-Phase Trip (DLX-B)*	YES / NO		NO
Ground Overcurrent Single-Phase Trip (DLX-B)*	YES / NO		NO
Zones Mask:			
87 Phases	YES / NO		NO
87 Ground	YES / NO		NO
87 Negative Sequence	YES / NO		NO

*** Enabling the first setting disables the second.**

Tripping Logic			
Setting	**In Display**	**Range**	**By default**
Auxiliary Units Activation Mask			
Thermal Image	THERMAL IMG	YES / NO	NO
Open Phase	OPEN PHASE	YES / NO	NO
Pole Discordance Detector	POLE DISCREP	YES / NO	NO
Phase Time Overcurrent (51-1)	TOC PH1	YES / NO	NO
Phase Time Overcurrent (51-2)	TOC PH2	YES / NO	NO
Phase Time Overcurrent (51-3)	TOC PH3	YES / NO	NO
Phase Instantaneous Overcurrent (50-1)	IOC PH1	YES / NO	NO
Phase Instantaneous Overcurrent (50-2)	IOC PH2	YES / NO	NO
Phase Instantaneous Overcurrent (50-3)	IOC PH3	YES / NO	NO
Ground Time Overcurrent (51N-1)	TOC GND1	YES / NO	NO
Ground Time Overcurrent (51N-2)	TOC GND2	YES / NO	NO
Ground Time Overcurrent (51N-3)	TOC GND3	YES / NO	NO
Ground Instantaneous Overcurrent (50N-1)	IOC GND1	YES / NO	NO
Ground Instantaneous Overcurrent (50N-2)	IOC GND2	YES / NO	NO
Ground Instantaneous Overcurrent (50N-3)	IOC GND3	YES / NO	NO
Negative Sequence Time Overcurrent (51Q-1)	TOC NEG SEQ1	YES / NO	NO
Negative Sequence Time Overcurrent (51Q-2)	TOC NEG SEQ2	YES / NO	NO
Negative Sequence Time Overcurrent (51Q-3)	TOC NEG SEQ3	YES / NO	NO
Negative Sequence Inst. Overcurrent (50Q-1)	IOC NEG SEQ1	YES / NO	NO
Negative Sequence Inst. Overcurrent (50Q-2)	IOC NEG SEQ2	YES / NO	NO
Negative Sequence Inst. Overcurrent (50Q-3)	IOC NEG SEQ3	YES / NO	NO
Phase Undervoltage (27-1)	UNDERVOLT PH1	YES / NO	NO
Phase Undervoltage (27-2)	UNDERVOLT PH2	YES / NO	NO
Phase Undervoltage (27-3)	UNDERVOLT PH3	YES / NO	NO
Phase Overvoltage (59-1)	OVERVOLT PH1	YES / NO	NO
Phase Overvoltage (59-2)	OVERVOLT PH2	YES / NO	NO
Phase Overvoltage (59-3)	OVERVOLT PH3	YES / NO	NO
Ground Overvoltage (59N-1)	OVERVOLT G1	YES / NO	NO
Ground Overvoltage (59N-2)	OVERVOLT G2	YES / NO	NO
Underfrequency (81m-1)	UNDFREQ1	YES / NO	NO
Underfrequency (81m-2)	UNDFREQ2	YES / NO	NO
Underfrequency (81m-3)	UNDFREQ3	YES / NO	NO
Overfrequency (81M-1)	OVERFREQ1	YES / NO	NO
Overfrequency (81M-2)	OVERFREQ2	YES / NO	NO
Overfrequency (81M-3)	OVERFREQ3	YES / NO	NO
Rate of Change (81D-1)	ROC FREQ1	YES / NO	NO
Rate of Change (81D-2)	ROC FREQ2	YES / NO	NO
Rate of Change (81D-3)	ROC FREQ3	YES / NO	NO

- **Tripping Logic: HMI Access (DLX-A Model)**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - OPEN POLE LOGIC
2 - ACTIVATE GROUP	2 - RECLOSER	2 - OVERCURRENT
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN PHASE DETECTOR
4 - INFORMATION	...	4 - CT SUPERVISION
		5 - THERMAL IMAGE
		6 - COLD LOAD
		7 - BREAKER FAILURE
		8 - POLE DISCREPANCY
		9 - PHASE SELECTOR
		10 - PROTECTION LOGIC

0 - LINE DIFFERENTIAL	
1 - OPEN POLE LOGIC	
2 - OVERCURRENT	**0 - FAULT DET. SUP.**
...	**1 - DIFFER. TRIP MASK**
10 - PROTECTION LOGIC	**2 - AUX UNITS MASK**
...	

- **Tripping Logic: HMI Access (DLX-B Model)**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	4 - OVERCURRENT
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - LINE DIFFERENTIAL	**0 - THREE PHASE TRIP**
1 - FUSE FAILURE	**1 - 1 PHASE TRIP 67G**
2 - DEAD LINE DETECTOR	**2 - 1 PHASE TRIP 87G**
...	**3 - FAULT DET. SUP.**
16 - PROTECTION LOGIC	**4 - DIFFER. TRIP MASK**
...	**5 - AUX UNITS MASK**

3.19.7 Digital Inputs and Events of the Tripping Logic

Table 3.19-1: Digital Inputs and Events of the Tripping Logic		
Name	**Description**	**Function**
INBLK_TRIP	Trip Blocking Input	Activation of this input produces a block of any trip.
ENBL_3PH	Three-phase Trip Enable Input	Activation of this input produces a three-phase trip ready.
INPROGTRIP	Programmable Trip Input	Activating this input causes a direct three-phase trip.
INBLK_3PHPREP	Three-phase Trip Preparation Block Input (DLX-B)	Activating this input disables the three-phase trip preparation.
INBLK_TRIP_A	Pole A Trip Block Input (DLX-B)	Activating this input disables pole A tripping.
INBLK_TRIP_B	Pole B Trip Block Input (DLX-B)	Activating this input disables pole B tripping.
INBLK_TRIP_C	Pole C Trip Block Input (DLX-B)	Activating this input disables pole C tripping.

3.19.8 Digital Outputs and Events of the Tripping Logic

Table 3.19-2: Digital Outputs and Events of the Tripping Logic		
Name	**Description**	**Function**
TRIP_A	Phase A Trip Output Activated (DLX-B)	Trip of A pole of the breaker.
TRIP_B	Phase B Trip Output Activated (DLX-B)	Trip of B pole of the breaker.
TRIP_C	Phase C Trip Output Activated (DLX-B)	Trip of C pole of the breaker.
TRIP_3PH	Three-Phase Trip (DLX-B)	Three-phase trip of the breaker.
TRIP	Trip	Trip of the breaker.
3PH_PREP	Three-Phase Trip Ready (DLX-B)	Three-Phase trip condition
INBLK_TRIP	Trip Blocking Input	The same as for the Digital Input.
ENBL_3PH	Three-Phase Trip Enable Input	The same as for the Digital Input.
INPROGTRIP	Programmable Trip Input	The same as for the Digital Input.
INBLK_3PHPREP	Three-Phase Trip Preparation Block Input (DLX-B)	The same as for the Digital Input.
INBLK_TRIP_A	Pole A Trip Block Input (DLX-B)	The same as for the Digital Input.
INBLK_TRIP_B	Pole B Trip Block Input (DLX-B)	The same as for the Digital Input.
INBLK_TRIP_C	Pole C Trip Block Input (DLX-B)	The same as for the Digital Input.

3.20 Recloser

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3.20.1 Description

DLX-B Model

DLX-B terminal unit Recloser allows up to four reclosing attempts, with independent reclosing timers (dead time delays) for the:

- First Single-Phase Reclosing Attempt.
- First Three-Phase Reclosing Attempt.
- Second Reclosing Attempt (always 3-Phase).
- Third Reclosing Attempt (always 3-Phase).
- Fourth Reclosing Attempt (always 3-Phase).

Also, the Recloser is able to operate in any of the following four modes:

1P Mode	Only single-phase reclosing is allowed. The Recloser will lockout after a three-phase trip. Therefore, this mode has a single reclosing attempt, independent of the number of attempts.
3P Mode	Only three-phase reclosing is allowed, forcing the tripping logic to make all the trips of this type.
1P / 3P Mode	Both single- and three-phase reclosing is allowed. The first attempt will be either single-phase or three-phase. The remaining attempts (depending on the **Reclosing Attempts** setting) will always be three-phase.
Dependent Mode	Only one reclosing will be attempted after a three-phase trip. For single-phase trips, the Recloser will operate according to the number of attempts selected in the **Reclosing Attempts** setting.

Figures 3.20.3, 3.20.4, 3.20.5, 3.20.6 and 3.20.7 show the Recloser operation flow diagrams with the details for each reclosing mode. In these diagrams, the signal **RCLS** (**Recloser Start Element Activated**) corresponds to the logic output in charge of generating the trips that are allowed to be reclosed by the associated Recloser Start Masks.

When **Number of Reclosers** setting is set to **Selection by DI**, the number of reclosers in operation will be defined by logic input **IN_1P** (**1P Mode Input**) and **IN_3P** (**3P Mode Input**) state based on the following table:

E_1P	E_3P	Result
0	0	Dependent Mode
0	1	3P Mode
1	0	1P Mode
1	1	1P/3P Mode

DLX-A Model

DLX-A terminal units Recloser allows up to four reclosing attempts (always 3-Phase), with independent reclosing timers (dead time delays).

Figure 3.20.8 shows the Recloser operation flow diagram with the details for each reclosing mode. In the diagram, the signal **RCLS** (**Recloser Start Element Activated**) corresponds to the logic output in charge of generating the trips that are allowed to be reclosed by the associated Recloser Start Masks.

3.20.2 External Trips

DLX-B Model

The Recloser operates in the same manner for trips generated by the **DLX-B** terminal unit or by external protection. Therefore, the four modes of operation are available to reclose trips generated by other protection terminals. To take advantage of this feature, the logic input signals **External A Pole Trip** (**IN_EXT_A**), **External B Pole Trip** (**IN_EXT_B**), **External C Pole Trip** (**IN_EXT_C**) or **External Protection Trip** (**IN_EXT**) and **External Protection Three-Phase Trip** (**IN_EXT_3PH**) must be used as follows:

1. When the external device only generates three-phase trips, the Recloser can operate connecting the **IN_EXT** and **IN_EXT_3PH** inputs or otherwise using only the **IN_EXT_3PH** input.
2. When the external device generates both single-phase and three-phase trips, the three **IN_EXT_A**, **IN_EXT_B** and **IN_EXT_C** inputs or otherwise the two **IN_EXT** and **IN_EXT_3PH** inputs should be connected.

DLX-A Model

The Recloser operates in the same manner for trips generated by the **DLX-A** terminal units or by external protection. To take advantage of this feature, the logic input signal **External Protection Three-Phase Trip** (**IN_EXT_3PH**) must be used.

3.20.3 Recloser Start Logic

DLX-B Model

The Recloser Start Logic is depicted in Figure 3.2O.1. As can be seen in this figure, the Recloser start can be produced when any Differential Unit (Phase, Ground or Negative Sequence), any of the Phase, Ground or Negative Sequence Overcurrent elements or the Open Phase unit or Protection Scheme is tripped, provided the **Recloser Start Mask** allows it.

Recloser start is also produced if an external trip is detected (if the **A Pole External Trip**, **B Pole External Trip**, **C Pole External Trip** inputs or otherwise the **External Trip** and **External Three-Phase Trip** inputs are programmed).

In all cases, the Recloser start is equivalent to **RCLS** signal activation. The remaining elements give rise to non-reclosable trips.

The Recloser will not start its close sequence if it detects that the number of trips has exceeded the set limit (see 3.20.2, Excessive Number of Trips) or if **IN_BLKRCLS (Recloser Initiate Block Input**) has been activated.

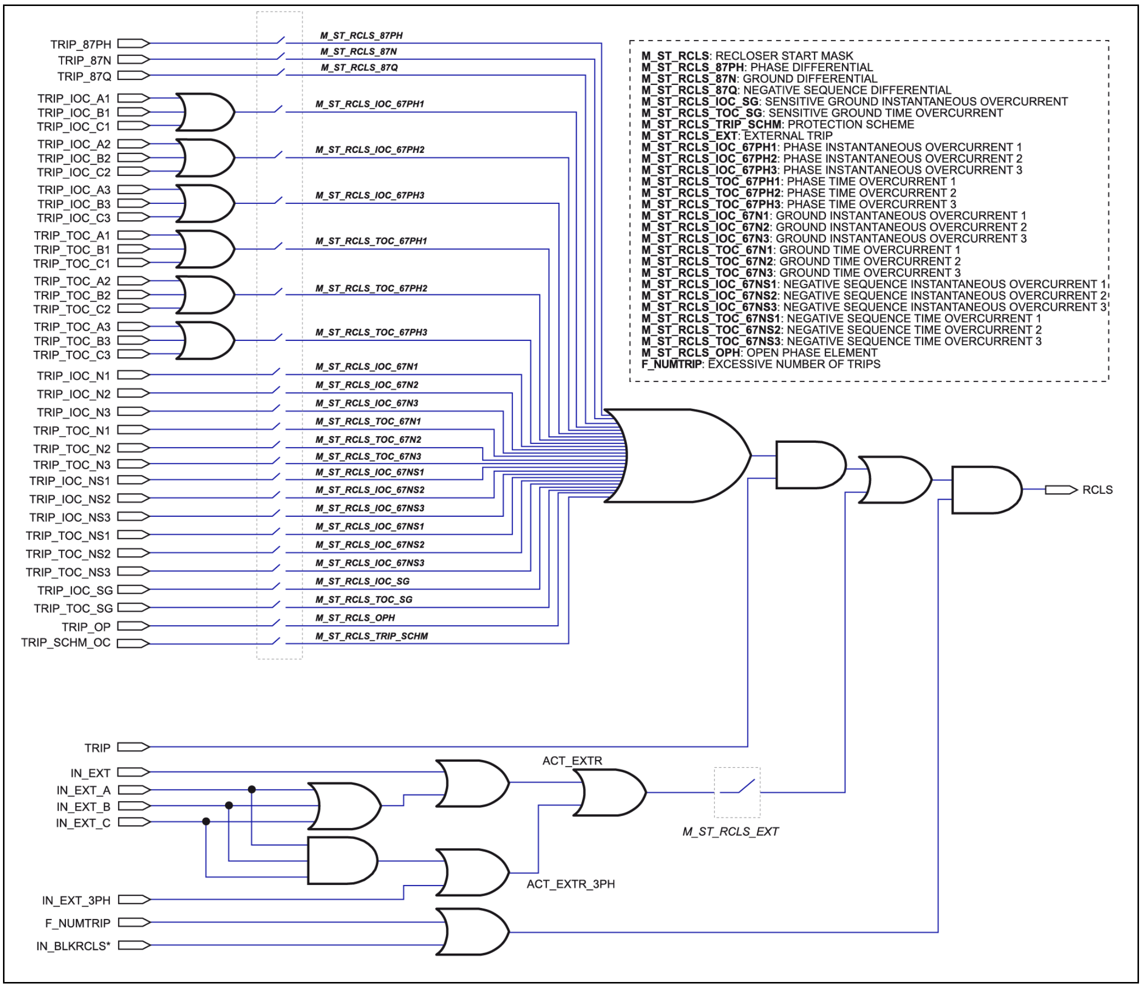

Figure 3.20.1 Recloser Sequence Start Logic Diagram (DLX-B Model).

DLX-A Model

The Recloser Start Logic is depicted in Figure 3.20.2. As can be seen in this figure, the Recloser start can be produced when any Phase, Ground or Negative Sequence Differential Unit, any of the Phase, Ground or Negative Sequence Overcurrent Elements or the Open Phase Unit trips, provided the **Recloser Start Mask** setting allows it. Recloser start is also produced whenever there is external trip. In all cases, the Recloser start is equivalent to **RCLS** signal activation. The remaining elements give rise to non-reclosable trips.

The Recloser will not initiate the closing cycle in case the number of trips is bigger than the setting value (see 3.20.2; Excessive Number of Trips) or, if **IN_BLKRCLS (Recloser Initiate Block Input**) has been activated.

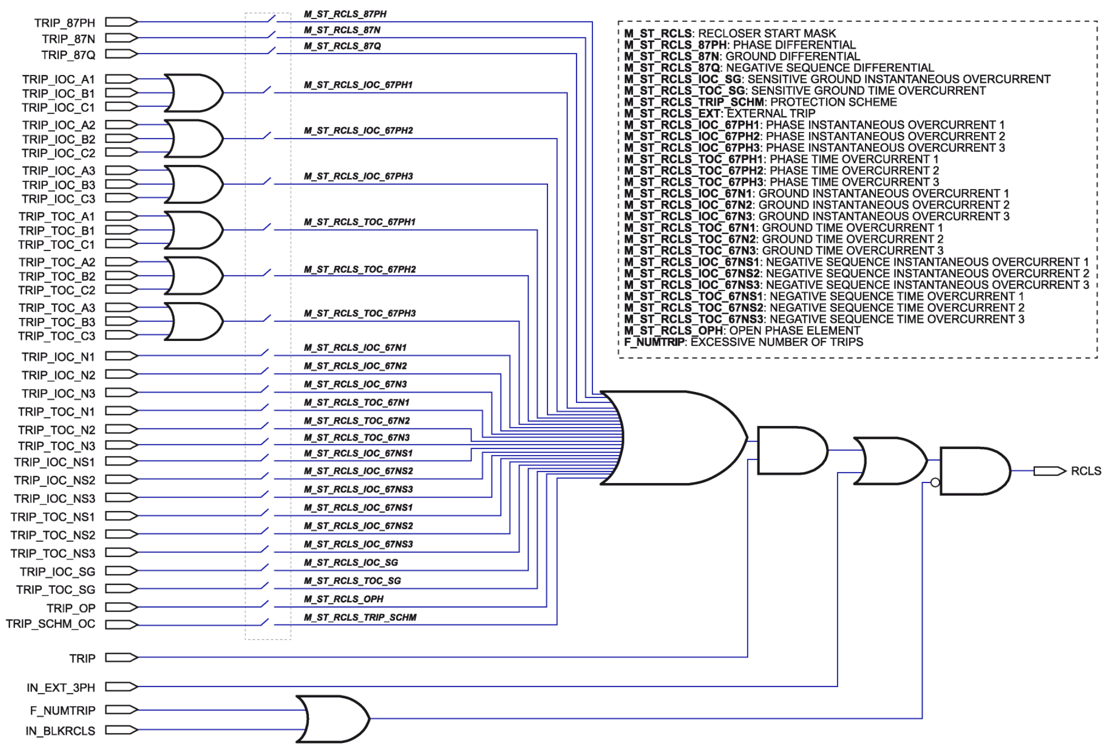

Figure 3.20.2 Recloser Sequence Start Logic Diagram (DLX-A Models).

3.20.4 Reclosing Logic

3.20.4.a Automatic Reclose with One Recloser

DLX-B Model

Figures 3.20.3, 3.20.4, 3.20.5 and 3.20.6 depict the flow diagrams for the four different Recloser operation modes. Figure 3.20.7 shows the block diagram of the Recloser Lockout. This last block diagram is common for each of the four reclosing modes.

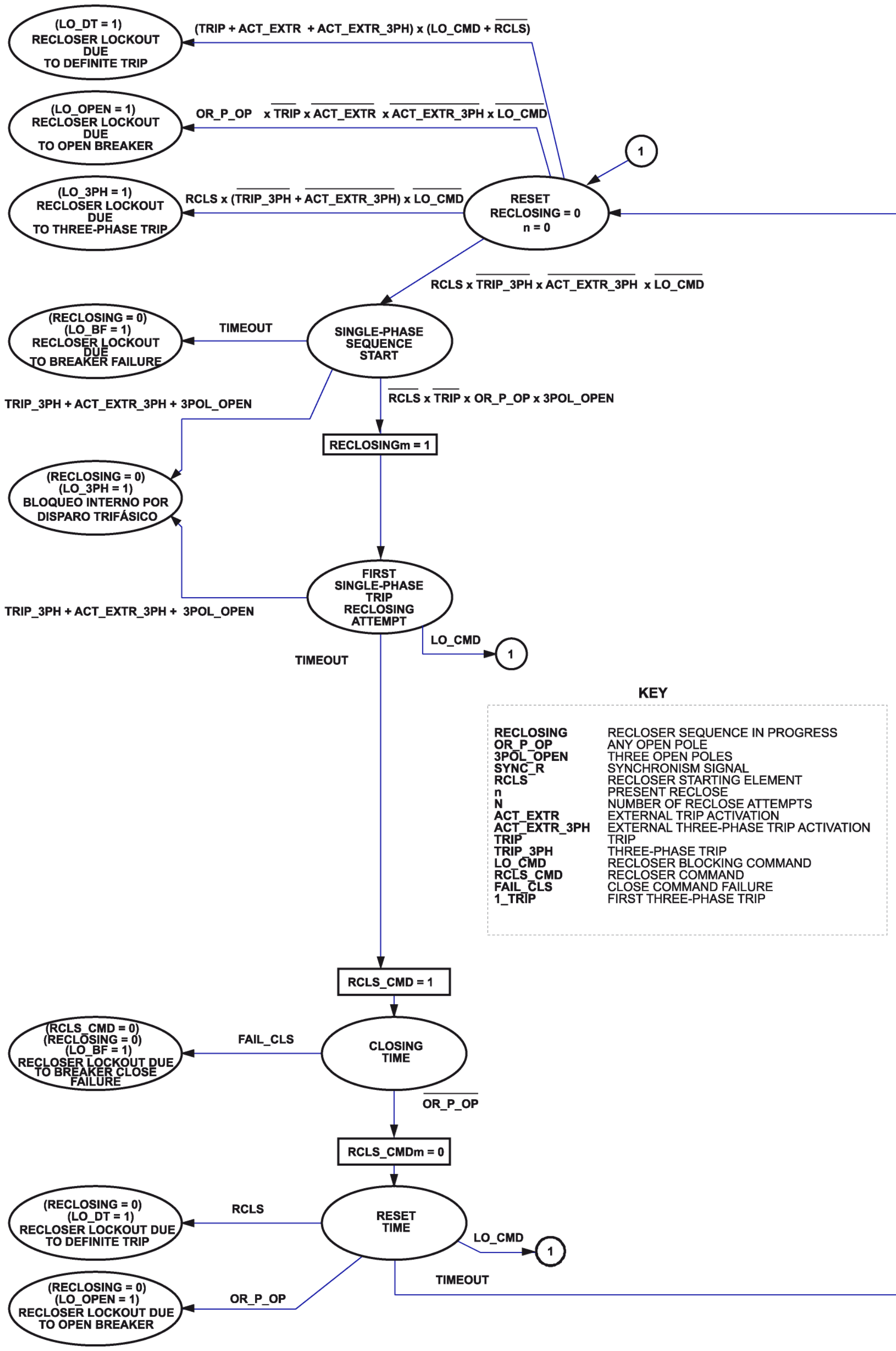

Figure 3.20.3 Recloser 1-P Mode 0peration Flow Diagram (I) for DLX-B Models.

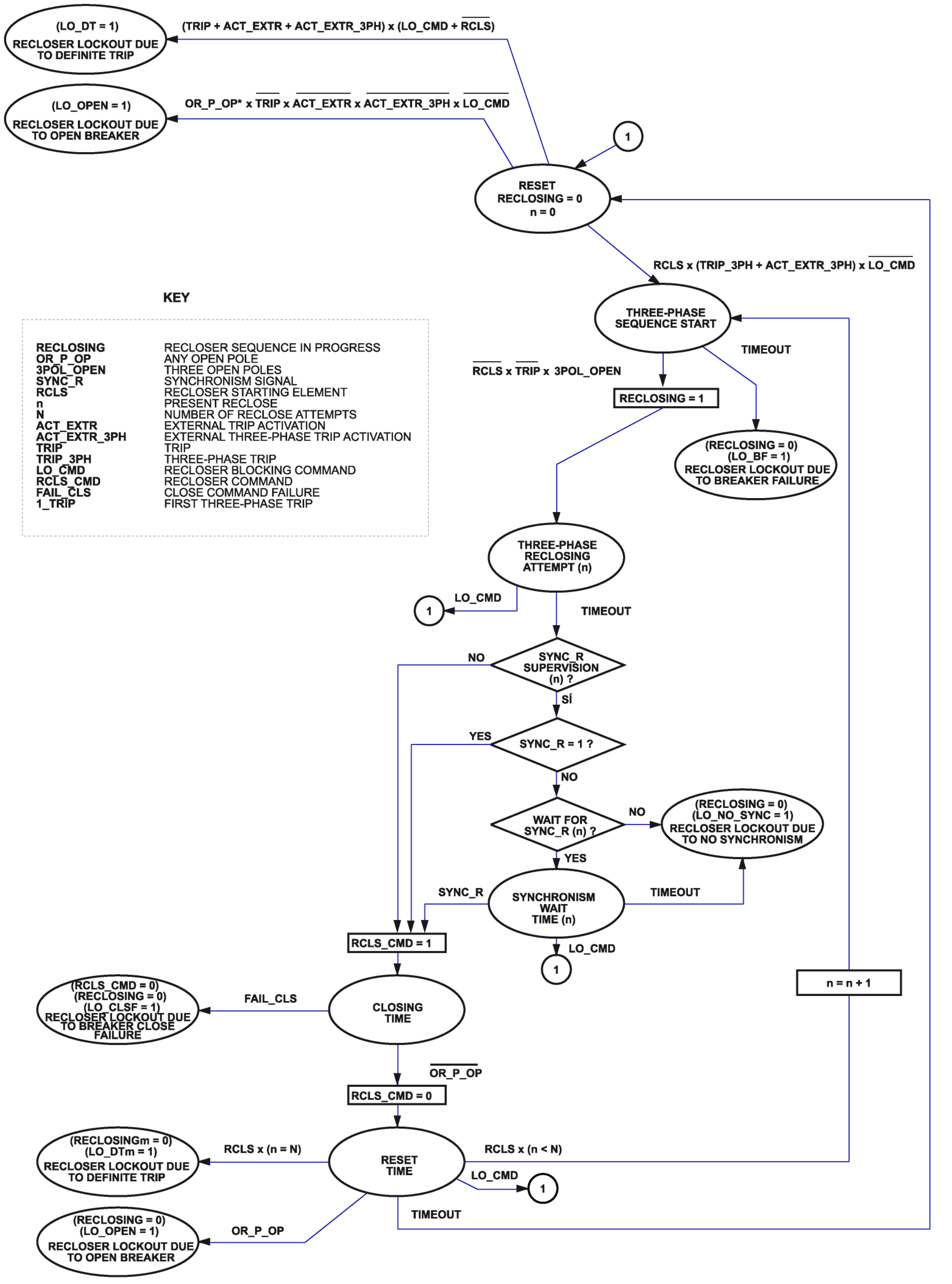

Figure 3.20.4 Recloser 3-P Mode Operation Flow Diagram (I) for DLX-B Models.

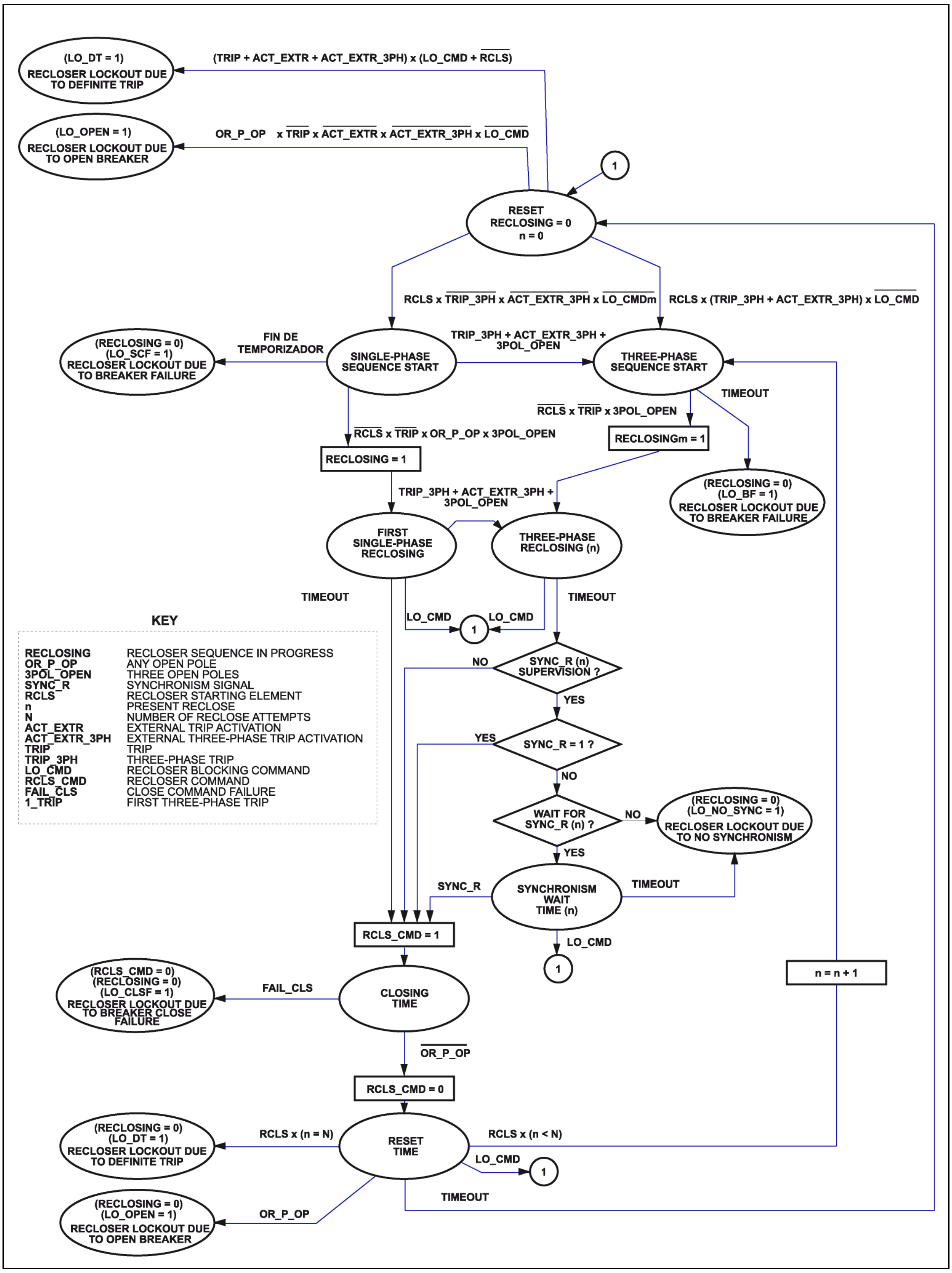

Figure 3.20.5 Recloser 1P / 3P Mode Operation Flow Diagram (I) for DLX-B Models.

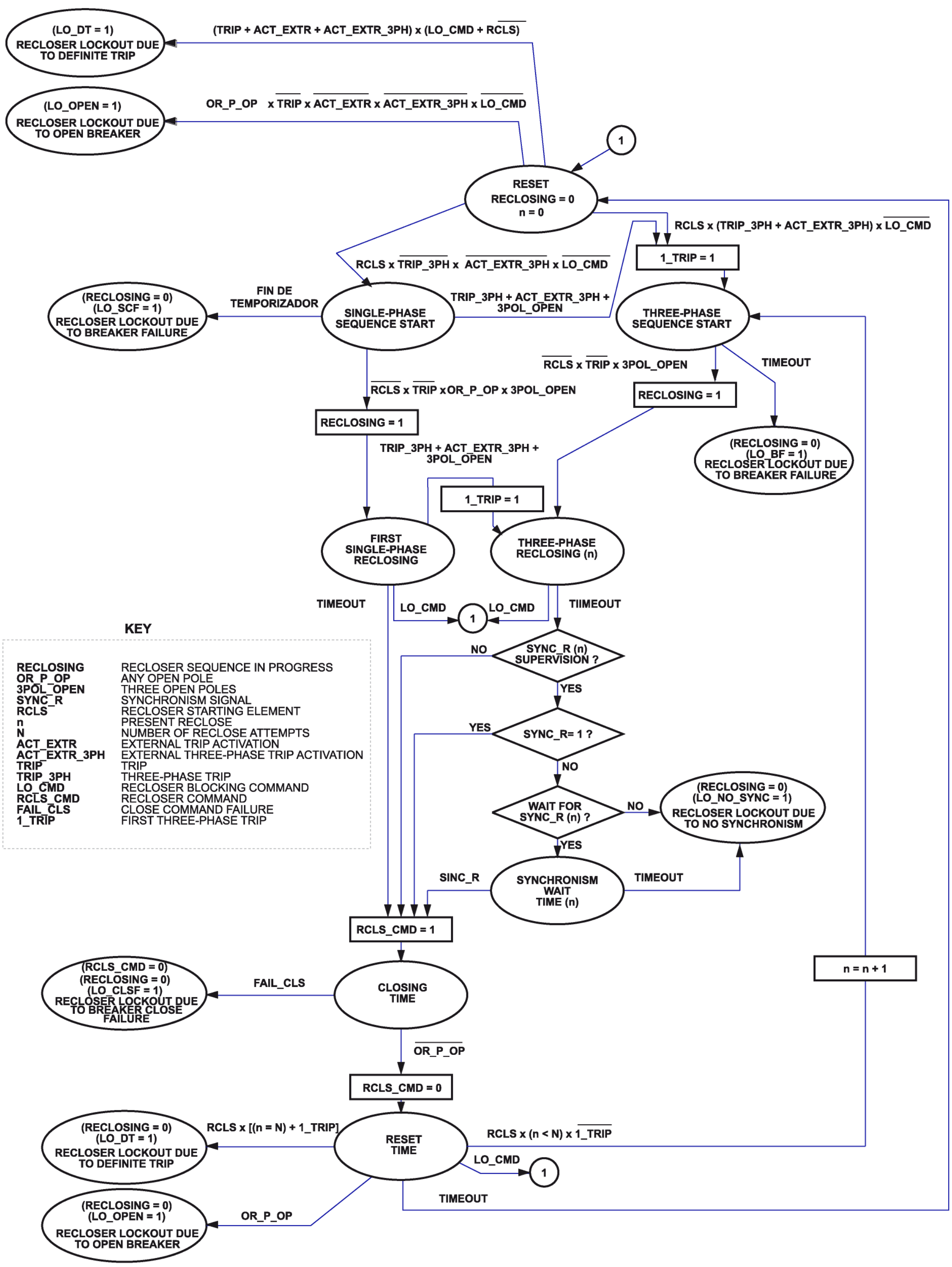

Figure 3.20.6 Recloser Dependent Mode Operation Flow Diagram (I) for DLX-B Models.

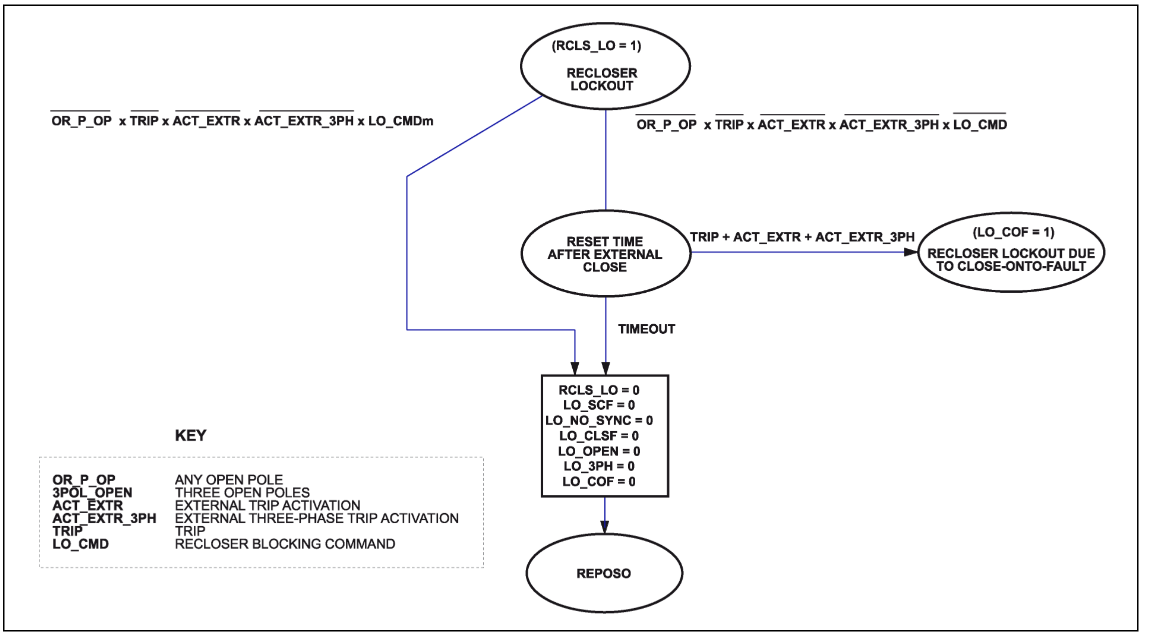

Figure 3.20.7 Recloser Operation Flow Diagram (II) for DLX-B Models.

DLX-A Model

Figure 3.20.8 depicts the Recloser operation flow diagrams.

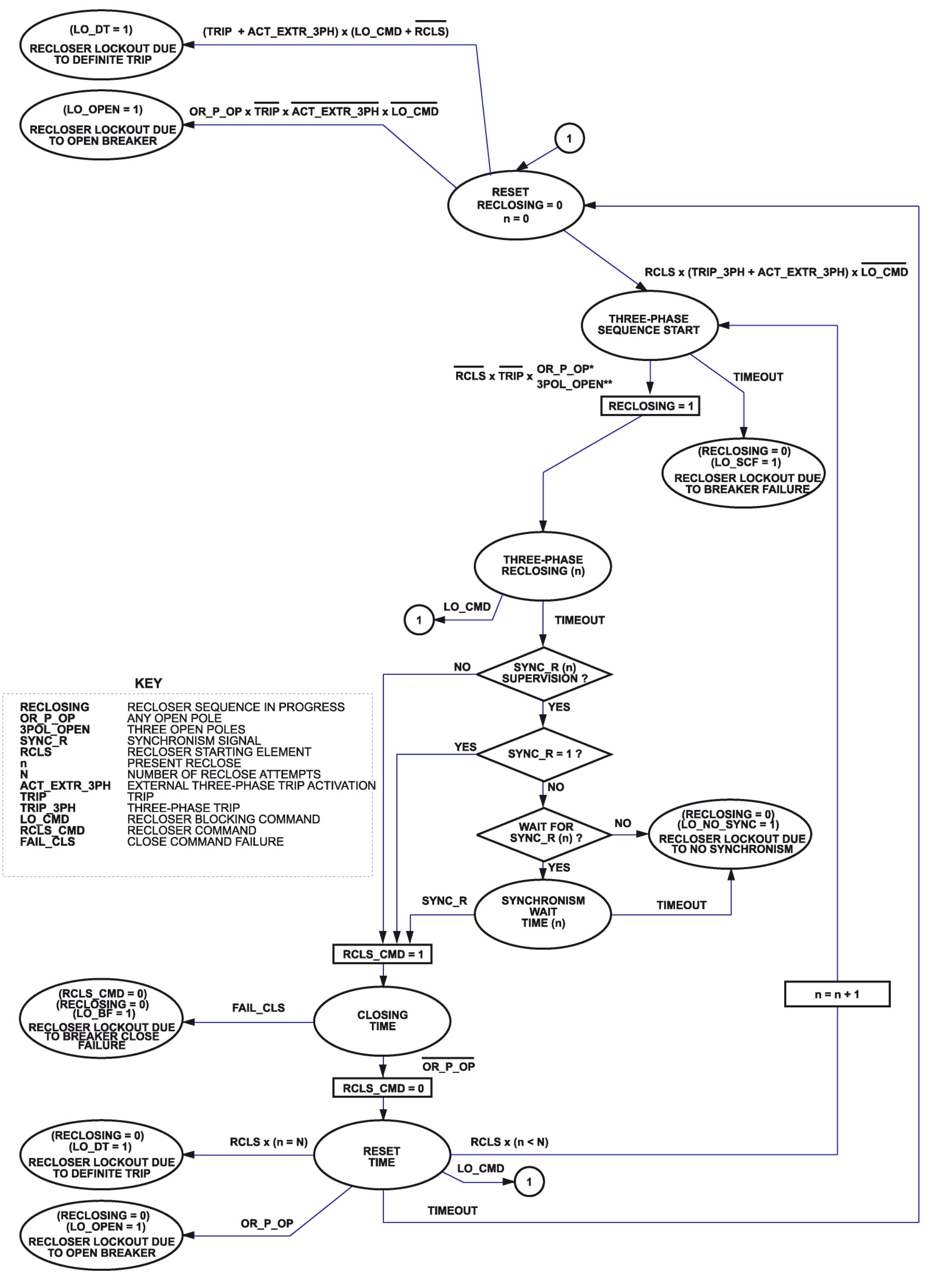

Figure 3.20.8 Recloser Operation Flow Diagram (DLX-A Model).

3.20.5 Reclose Sequence

Up to four reclose attempts can be programmed in the reclose sequence. A sequence of operations takes place during each of these close attempts which is controlled by the Recloser settings and by certain external events, detected through the digital input system or received from the protection units contained in the **DLX** IED itself. Below are represented the different states of the automatic reclose function.

3.20.5.a Sequence Start

- **DLX-B Model**

The **DLX-B** Recloser presents two start time states (**Single-Phase Start Time** state and **Three-Phase Start Time** state). When the Recloser is in the Recloser Reset state, reclosing is initiated as follows:

- In **1P Mode**, the operation starts on a single-phase trip being produced by any of the enable protection units or by the **External Trip Activation** (**ACT_EXTR**) signal, with the **External Three-Phase Activation Trip** (**ACT_EXTR_3PH**) deactivated.
  In either of the two cases, the **RCLS** signal will be activated, which will remove the Recloser from its Reset state to change it to the Single-Phase Start Time state provided the Recloser is not blocked by command (see 3.20.7).
  If the **RCLS** activation is due to **Three-Phase Trip** (**TRIP_3PH** or **ACT_EXTR_3PH**), the Recloser evolves the Internal **Blocking Due to Three-Phase Trip** state instead of starting a reclose sequence.
- In **3P Mode**, the operation starts on one of the enabled protection units producing a three-phase trip or by the **External Three-Phase Activation Trip** (**ACT_EXTR_3PH**) signal.
  In either of the two cases, the **RCLS** signal will be activated, which will remove the Recloser from its Reset State to change it to the **Three-Phase Start Time** state provided the Recloser is not blocked by command (see 3.20.7).
- In **1p/3p** and **Dependent** modes, the operation of the Recloser is based on the combination of the two previous modes (**1p** for single-phase trips and **3p** for three-phase trips).

Single-Phase Sequence Start

In the **Single-Phase Start Time** state, a time counter with **Start Time** setting is put into operation. If this time ends before detecting the fault reset (**RCLS** reset), the opening of the breaker ($OR\_P\_OPx\ \overline{AND\_P\_OP}$) and the trip drop (**TRIP**), the system evolves to the **Internal Blocking Due to Breaker Failure** state, from which it can only leave through a close command to the breaker. Otherwise, the single-phase sequence starts activating the **RECLOSING** (Sequence in Progress) signal and generating the **Recloser Sequence Start**. The activation of **RECLOSING** produces the activation of **3PH_PREP** (**Three-Phase Trip Ready** signal), as is indicated in the single-phase/three-phase Tripping Logic, with which the following trips will be three phase up to the deactivation of **RECLOSING**.

Note: The RECLOSING signal will remain activated during the entire Recloser m sequence, since the first attempt sequence will continue until the Recloser switches to the Reset or the Lockout state.

If the single-phase trip evolves to three-phase before the initiate timer times out, the Recloser switches to:

- **Internal Lockout on Three-Phase Trip**, in **1p Mode**.
- **Three-Phase Initiate Time**, in **1p/3p** and **Dependent Modes**.

Three-Phase Sequence Start

In the **Three-Phase Start Time** state, a time counter is put into operation with the **Start Time** setting. As in the single-phase case, if this time ends before the fault reset is detected (**RCLS** reset), the opening of the breaker (**OR_P_OP**) and trip drop (**TRIP**), the system evolves to the **Internal Blocking Due to Breaker Failure** state, from which it can only leave through a **Close Command** to the breaker. Otherwise, the three-phase sequence commences activating the **RECLOSING** (Sequence in Progress) signal and generating the **Recloser Sequence Start**. The activation of **RECLOSING** produces the activation of **3PH_PREP** (**Three-Phase Trip Ready** signal), as is indicated in the single-phase/three-phase Tripping Logic, with which the following trips will be three phase up to the deactivation of **RECLOSING**.

Note: The RECLOSING signal will remain activated during the entire Recloser m sequence, since the first attempt sequence will continue until the Recloser switches to the Reset or the Lockout state.

If the single-phase trip evolves to three-phase (activation of **TRIP_3PH** or **ACT_EXTR_3PH** signals) or if the breaker opens its three poles (activation of **AND_P_OP**) before the initiate timer times out, the Recloser m switches to:

- **Internal Lockout on Three-Phase Trip**, in **1p Mode**.
- **Three-Phase Initiate Time**, in **1p/3p** and **Dependent Modes**.

- **Automatic Recloser with 1 Recloser. DLX-A Models**

From an Recloser Reset state, the operation of the Recloser commences on producing a Three-Phase Trip by any of the protection units enabled or by the **External Three-Phase Trip Activation** (**ACT_EXTR_3PH**) signal.

In either of the two cases, the **RCLS** signal will be activated, which will remove the Recloser from its **Reset** state to change it to the **Start Time** state provided that the Recloser is not blocking by command.

In the **Start Time** state, a time counter with **Start Time** setting is put into operation. If this time ends before detecting the fault reset (**RCLS** reset), the opening of the breaker (**OR_P_OP**) and the trip drop (**TRIP**), the system evolves into the Internal **Blocking Due to Breaker Failure** state, from which it can only leave through a **Close Command** to the breaker. Otherwise, the sequence commences activating the **RECLOSING** (**Sequence in Progress**) signal and generating the **Recloser Sequence** start.

Note: The RECLOSING signal will remain activated during the entire Recloser sequence, since the first attempt sequence will continue until the Recloser switches to the Reset or the Lockout state.

3.20.5.b Reclosing Timer (Dead Time)

- **Automatic Recloser with 1 Recloser. DLX-B Models**

There are two different reclosing timers, according to the single-phase or three-phase character of the Reclose start. In both cases, the activation of the **Reclose Command** (**RCLS_CMD**) will produce the activation of the **Command CLOSE** output, with the latter giving a **Close Command** to the breaker.

Single-Phase Reclosing Timer

On entering this state (which only occurs in the first sequence of the **1P** and **1P/3P** modes), the adjusted **First Single-Phase Reclosing Time** will commence to be counted.

If a Recloser block command is issued (activation of **LO_CMD**) before the timer times out, the Recloser resets without reclosing. On the other hand, if the single-phase trip evolves to three-phase (activation of **TRIP_3PH** or **ACT_EXTR_3PH** signals) or if the breaker opens the three poles (activation of **AND_P_OP** signal) before the single-phase reclose time times out, the Recloser switches to:

- **Internal Lockout on Three-Phase Trip** state, in **1p Mode**.
- **Three-Phase Initiate Time** state, in **1p/3p** and **Dependent Modes**.

Otherwise, if the counted timer times out the **Reclose Command** signal (**RCLS_CMD**) is generated and the **Closing Time** state is achieved.

Three-Phase Reclosing Timer

When the Three-Phase Reclosing Timer state is achieved, the corresponding timer will be started:

- The **First Three-Phase Reclosing Timer** will start for the first reclosing attempt after a three-phase trip.
- The **Second or Third Reclosing Timer** will start for a second or third reclosing sequence (as previously noted, only three-phase reclosing is possible after the first Recloser sequence).

As in the case of Single-Phase Reclosing Time, if the Recloser is manually blocked (**LO_CMD** activation) before the count ends, the Recloser returns to Reset state without reclosing. On the other hand, if the count ends, it is verified if synchronism conditions exist and then **RCLS_CMD** (**Reclose Command**) is activated if the synchronism conditions have been previously fulfilled.

The **Synchronism Supervision** setting may be adjusted independently for each Recloser sequence. If the **Synchronism Supervision** setting for the corresponding sequence is set to **NO**, the **Reclose Command** signal (**RCLS_CMD**) is generated and the **Closing Time** state is achieved.

If the **Synchronism Supervision** setting for the corresponding sequence is set to **YES**, the next step is to check the **SYNC_R** signal, which indicates the presence of synchronous conditions. If this signal is activated, the **Reclose Command** signal (**RCLS_CMD**) is generated and the **Closing Time** state is achieved.

When synchronous conditions are not reached (**SYNC_R** deactivated), the **Synchronism Timer Enable** setting, independently adjustable for each of the three possible sequences of the Recloser function, is checked. If this setting is set to **NO**, the Recloser changes to the **Internal Lockout Due to Lack of Synchronism** state. If the setting is set to **YES**, the **Synchronism Wait Timer** starts to count down the adjusted time.

Activation of the **SYNC_R** signal before timeout generates activation of the **Reclose Command** signal (**RCLS_CMD**), and the **Closing Time** state is achieved. If the **SYNC_R** signal is not activated before timeout, the Recloser changes to the Internal **Lockout Due to Lack of Synchronism** state.

- **Automatic Recloser with 1 Recloser. DLX-A Models**

On entering this state it will commence to count the corresponding **Reclosing Time** (first, second or third reclosing).

If the Recloser is manually blocked (**LO_CMD** activation) before the count ends, the Recloser returns to Reset state without reclosing. On the other hand, if the count ends, it is verified if synchronism conditions exist and then **RCLS_CMD** (Reclose Command) is activated if the synchronism conditions have been previously fulfilled.

The **Synchronism Supervision** setting may be adjusted independently for each Recloser sequence. If the **Synchronism Supervision** setting for the corresponding sequence is set to **NO**, the **Reclose Command** signal (**RCLS_CMD**) is generated and the **Closing Time** state is achieved. If the **Synchronism Supervision** setting is set to **YES**, the next step is to check the **SYNC_R** signal, which indicates the presence of synchronous conditions. If this signal is activated, the **Reclose Command** signal (**RCLS_CMD**) is generated and the **Closing Time** state is achieved.

When synchronous conditions are not reached (**SYNC_R** deactivated), the **Synchronism Timer Enable** setting, independently adjustable for each of the three possible sequences of the Recloser function, is checked. If this setting, for the corresponding sequence, is set to **NO**, the Recloser changes to the **Internal Lockout Due to Lack of Synchronism** state. If the setting is set to **YES**, the **Synchronism Wait Timer** starts to count down the adjusted time.

Activation of the **SYNC_R** signal before timeout generates activation of the **Reclose Command** signal (**RCLS_CMD**), and the **Closing Time** state is achieved. If the **SYNC_R** signal is not activated before timeout, the Recloser changes to the **Internal Lockout Due to Lack of Synchronism** state.

The activation of the **Reclose Command** (**RCLS_CMD**) will produce the activation of the **Command CLOSE** output, with the latter giving a close command to the breaker.

3.20.5.c Closing Time

After issuing the **Reclose Command**, the Recloser switches to the **Waiting for Closing** state, in which setting **Close Command Failure Time** set via the **Command** module (see 3.21) starts timing. If the timer times out before the three poles of the breaker close (deactivation of the **Any Pole Open**, **OR_P_OP** signal) the **FAIL_CLS** output (**Close Command Failure**) activates and the Recloser switches to **Internal Lockout on Close Failure** state. If during the **Command Failure** time the three breaker poles are closed, the Recloser will switch to **Safety Time** state.

Once the Reclose Command is generated, the Recloser changes to **Wait to Close** state, in which, within a maximum time equal to **Close Command Failure Time** setting of the **Command**, it will receive one of the following signals. In both cases, the **RCLS_CMD** output will be deactivated.

3.20.5.d Safety Time

DLX-B Model

When reaching this state, a timer with the setting **Safety Time**, common for the three Recloser sequences, starts timing. Said time is used to discern whether two consecutive trips correspond to the same fault, which has not successfully been cleared, or to two consecutive faults. If **Safety Time** times out with no trip occurring, the Recloser switches to **Reset** state.

If a trip occurs (**RCLS** signal activated) before **Safety Time** times out, the next step depends on whether the number of programmed reclose attempts has been reached or not. If this limit has been reached or if the Recloser operates in dependent mode the first trip being three-phase (see consultation of **1_TRIP** signal in figure 3.20.6), both reclosers switch to **Internal Lockout on Final Trip**, the sequence being completed. Otherwise, a new trip initiates a new close sequence, system switching to **Three-phase Initiate Time** state.

Opening any breaker pole before **Safety Time** times out switches the Recloser to **Lockout on Breaker Open** state. It switches to the **Reset** state if the Recloser is blocked (**Blocking Command**) before **Safety Time** times out.

DLX-A Model

When reaching this state, a timer with the setting **Safety Time**, common for the three Recloser sequences, starts timing. Said time is used to discern whether two consecutive trips correspond to the same fault, which has not successfully been cleared, or to two consecutive faults. If **Safety Time** times out with no trip occurring, the Recloser switches to **Reset** state.

If a trip occurs (**RCLS** signal activated) before **Safety Time** times out, the next step depends on whether the number of programmed reclose attempts has been reached or not. If this limit has been reached or if the Recloser operates in dependent mode the first trip being three-phase (see consultation of **1_TRIP** signal in figure 3.20.8), both reclosers switch to **Internal Lockout on Final Trip**, the sequence being completed. Otherwise, a new trip initiates a new close sequence, system switching to **Initiate Time** state.

Opening any breaker pole before **Safety Time** times out switches the Recloser to **Lockout on Breaker Open** state. It switches to the **Reset** state if the Recloser is blocked (**Blocking Command**) before **Safety Time** times out.

3.20.6 Recloser Lockout

- **Automatic Reclose with One Recloser**

The **Lockout** states correspond to situations in which the Recloser will not initiate its sequence in case of a trip and, consequently, all those produced under these circumstances are definite.

In the previous statement, the Internal Lockout states to which the Recloser can arrive once the Recloser abandons the **Reset** state as a result of a fault and its corresponding trip are defined. However, there are other circumstances which may result in the internal lockout of the Recloser and this is the opening of the breaker not associated with a fault. Under these circumstances, the Recloser will change to the **Internal Lockout Due to Open Breaker** state, remaining unable to carry out the closing.

The Recloser will remain in any of the Internal Lockout states reached until it detects the closing of the breaker. When this situation is detected, the Recloser will abandon the **Internal Lockout** state reached and will change to the **Reset Time after an External Closing** state. On entering this state, the count of the **Reset Time after an External Closing** setting commences. If the count ends without any trip having been produced (from the equipment or external), the Recloser will change to Reset state. If, on the other hand, a trip is produced before the time ends, the Recloser will change to the Internal **Blocking Due to Close onto a Fault** state and the trip will be definite, without subsequent reclosing.

3.20.7 Recloser Block Command (Manual or External)

The Recloser is provided with two types of blocking commands which take it to the Block Command state: **Manual Command** and **External Command**.

The **Manual** and **External Blocking Commands** are produced through the activation of the **INBLK_MAN** (**Recloser Manual Block Command**) and **INBLK_EXT** (**Recloser External Block**) logic inputs, respectively. The objective of the **INBLK_MAN** logic input is to receive signals originating from the HMI or communications (in local or remote mode), while the **INBLK_EXT** logic input is for the purpose of receiving external signals, which will arrive through the digital inputs of the equipment.

Manual Blocking Command is always by pulse; entering into the **Block Command** state will occur with an activation pulse from the **INBLK_MAN** (**Recloser Manual Block Command**), while the exiting of this state requires a complementary unblocking command, which will be issued by an activation pulse of the **IN_UNBLK_MAN** (**Recloser Manual Unblock Command**) input or **IN_UNBLK_EXT** (**Recloser External Unblock Command**) input, provided that the **External Blocking Type** setting is in Pulse.

External Blocking Command may be a pulse or level, according to the **External Blocking Type** setting. When this setting is in **Pulse**, the entry into Block Command state will occur with an activation pulse of the **INBLK_EXT** (**Recloser External Block**) input, while the output of this state will be produced with an activation pulse of the **IN_UNBLK_EXT** (**External Unblocking**) or **IN_UNBLK_MAN** (**Manual Unblocking**) inputs. However, if the **External Blocking Type** setting is **Level**, the blocking as well as the unblocking of the Recloser will be produced through the **INBLK_EXT** input. If this input is at **1**, the Recloser will be blocked; if it is at **0**, it will be unblocked. In this case, while the **INBLK_EXT** input is activated, the state of the **IN_UNBLK_EXT** and **IN_UNBLK_MAN** inputs will not be considered; even if these inputs are at **1**, the Recloser will continue to be blocked.

If the Recloser is in a reclose sequence, it will be stopped on receiving the Block Command, changing to the Reset state. In this state, no reclosing attempt will be made after tripping, which would be, in all cases, definite, generating the **Internal Lockout Due to Definite Trip** event.

If with the Recloser blocked and in a reset state, an Unblocking Command is received and the breaker is open, the Recloser would change to **Internal Lockout Due to Open Breaker** state from which it leaves on the breaker closing. If, on the other hand, the breaker is closed, the Recloser will remain in the Reset state.

3.20.8 Definite Trip

The Recloser will generate a **Recloser in Internal Lockout Due to Definite Trip** (**LO_DT** output) signal when a trip is produced with the Recloser **Blocking by Command** or in circumstances such that the Recloser Start Element Activated signal (**RCLS**) is not activated. In this case, the Recloser changes to the Internal **Lockout Due to Definite Trip** state.

Although not expressed in the flow diagrams, each time that the **LO_3PH** (**Internal Lockout Due to Three-Phase Trip**), **LO_SCF** (**Internal Lockout Due to Breaker Failure**), **LO_BF** (**Internal Lockout Due to Close Failure**) and **LO_NO_SYNC** (**Internal Lockout Due to Synchronism Failure**) signals are activated, the **LO_DT** (**Internal Lockout Due to Definite Trip**) signal should also be activated.

3.20.9 Recloser Not in Service

The Recloser is placed in the Not in Service state whenever the Recloser **Enable** setting is **NO**.

If it is required to use an external Recloser with the model **DLX-B**, in order to guarantee that all the trips are three phase after a single-phase reclosing, it is necessary to wire the **Sequence in Progress** output of the external Recloser to the **Three-Phase Trip Enable** (**ENBL_3PH**) input.

3.20.10 Reclose Counter

- **DLX-A Models**

There is one counter accessible from the operator interface display, which indicates the number of reclose attempts completed. The counter can be reset from the operator interface, by digital input or via communications.

- **DLX-B Models**

There are two counters accessible from the operator interface display, which indicate the number of reclose attempts completed. The counters can be reset from the operator interface, by digital input or via communications. One counter records the number of single-phase reclose attempts, and the second counts the three-phase reclose attempts. For example, when the number of reclose attempts is set to three, and a fault has been successfully cleared after the third trip, the first counter is incremented one count and two counts in the second.

3.20.11 Recloser Settings

Recloser In Service			
Setting	**Range**	**Step**	**By default**
Recloser in Service	YES / NO		NO

Recloser Timers			
Setting	**Range**	**Step**	**By default**
First Single-Phase Reclosing Attempt Delay (DLX-B)	0.05 - 300 s	0.01 s	1 s
First Three-Phase Reclosing Attempt Delay	0.05 - 300 s	0.01 s	0.5 s
Second Reclosing Attempt Delay	0.05 - 300 s	0.01 s	0.5 s
Third Reclosing Attempt Delay	0.05 - 300 s	0.01 s	0.5 s
Forth Reclosing Attempt Delay	0.05 - 300 s	0.01 s	0.5 s

Sequence Control Time			
Setting	**Range**	**Step**	**By default**
Sequence Check (Start) Time	0.07 - 0.60 s	0.01 s	0.2 s
Reset Time	0.05 - 300 s	0.01 s	10 s
Manual Close Reset Time	0.05 - 300 s	0.01 s	5 s
Synchronism Check Time Delay	0.05 - 300 s	0.01 s	5 s

Sequence Control			
Setting	**Range**	**Step**	**By default**
Reclosing Mode (DLX-B)	1P Mode 3P Mode 1P / 3P Mode Dependent Mode Selection by DI		1P Mode
Number of Reclose Attempts	1 - 4		3
External Blocking	Level / Pulse		Level

Recloser Start Mask			
Setting	**In Display**	**Range**	**By default**
Phase Differential Unit	87 Phase	YES / NO	NO
Ground Differential Unit	87 Ground	YES / NO	NO
Negative Sequence Differential Unit	87 Neg Seq	YES / NO	NO
Open Phase Detector	OPEN PHASE	YES / NO	NO
Phase Time Overcurrent (51-1)	TOC PH1	YES / NO	NO
Phase Time Overcurrent (51-2)	TOC PH2	YES / NO	NO
Phase Time Overcurrent (51-3)	TOC PH3	YES / NO	NO
Phase Instantaneous Overcurrent (50-1)	IOC PH1	YES / NO	NO
Phase Instantaneous Overcurrent (50-2)	IOC PH2	YES / NO	NO
Phase Instantaneous Overcurrent (50-3)	IOC PH3	YES / NO	NO
Ground Time Overcurrent (51N-1)	TOC GND1	YES / NO	NO
Ground Time Overcurrent (51N-2)	TOC GND2	YES / NO	NO
Ground Time Overcurrent (51N-3)	TOC GND3	YES / NO	NO
Sensitive Ground Time Overcurrent (51NS)	TOC SG	YES / NO	NO
Ground Instantaneous Overcurrent (50N-1)	IOC GND1	YES / NO	NO
Ground Instantaneous Overcurrent (50N-2)	IOC GND2	YES / NO	NO
Ground Instantaneous Overcurrent (50N-3)	IOC GND3	YES / NO	NO
Sensitive Ground Instantaneous Overcurrent (50NS)	IOC SG	YES / NO	NO
Negative Sequence Time Overcurrent (51Q-1)	TOC NEG SEQ1	YES / NO	NO
Negative Sequence Time Overcurrent (51Q-2)	TOC NEG SEQ2	YES / NO	NO
Negative Sequence Time Overcurrent (51Q-3)	TOC NEG SEQ3	YES / NO	NO
Negative Sequence Inst. Overcurrent (50Q-1)	IOC NEG SEQ1	YES / NO	NO
Negative Sequence Inst. Overcurrent (50Q-2)	IOC NEG SEQ2	YES / NO	NO
Negative Sequence Inst. Overcurrent (50Q-3)	IOC NEG SEQ3	YES / NO	NO
Programmable Trip	Prog Trip	YES / NO	NO

Synchronism Check Supervision*			
Setting	**Range**	**Step**	**By default**
Synchronism Check Supervision Enable			
1st Reclosing Supervision	YES / NO		NO
2nd Reclosing Supervision	YES / NO		NO
3rd Reclosing Supervision	YES / NO		NO
4th Reclosing Supervision	YES / NO		NO
Synchronism Check Wait Enable			
1st Reclosing Wait Time	YES / NO		NO
2nd Reclosing Wait Time	YES / NO		NO
3rd Reclosing Wait Time	YES / NO		NO
4th Reclosing Wait Time	YES / NO		NO

- **Recloser: HMI Access (DLX-A Model)**

0 - CONFIGURATION	0 - GENERAL	**0 - IN SERVICE**
1 - OPERATIONS	1 - PROTECTION	**1 - RECLOSER TIMERS**
2 - ACTIVATE GROUP	**2 - RECLOSER**	**2 - SEQ CONTROL TIMER**
3 - CHANGE SETTINGS	3 - LOGIC	**3 - SEQUENCE CONTROL**
4 - INFORMATION	...	**4 - RECLOSER INIT MASK**
		5 - SYNCROCHECK SUPERV.

Recloser Timers

0 - GENERAL	0 - IN SERVICE	**0 - 1ST 3PH RECL ATTEMPT**
1 - PROTECTION	**1 - RECLOSER TIMERS**	**1 - 2ND RECLOS ATTEMPT**
2 - RECLOSER	2 - SEQ CONTROL TIMER	**2 - 3RD RECL. ATTEMPT**
3 - LOGIC	3 - SEQUENCE CONTROL	**3 - 4TH RECL. ATTEMPT**
...	4 - RECLOSER INIT MASK	
	5 - SYNCROCHECK SUPERV.	

Sequence Control Timers

0 - GENERAL	0 - IN SERVICE	**0 - START TIME**
1 - PROTECTION	1 - RECLOSER TIMERS	**1 - SECURITY TIME**
2 - RECLOSER	**2 - SEQ CONTROL TIMER**	**2 - MC RESET TIME**
3 - LOGIC	3 - SEQUENCE CONTROL	**3 - SYNC WAIT TIME**
...	4 - RECLOSER INIT MASK	
	5 - SYNCROCHECK SUPERV.	

Sequence Control

0 - GENERAL	0 - IN SERVICE	
1 - PROTECTION	1 - RECLOSER TIMERS	
2 - RECLOSER	2 - SEQ CONTROL TIMER	**0 - RECLOSE ATTEMPTS**
3 - LOGIC	**3 - SEQUENCE CONTROL**	**1 - EXTERNAL BLOCKING**
...	4 - RECLOSER INIT MASK	
	5 - SYNCROCHECK SUPERV.	

Synchronism Check Supervision

0 - GENERAL	0 - IN SERVICE	
1 - PROTECTION	1 - RECLOSER TIMERS	
2 - RECLOSER	2 - SEQ CONTROL TIMER	
3 - LOGIC	3 - SEQUENCE CONTROL	
...	4 - RECLOSER INIT MASK	**0 - SYNC. SUPERV. ENABLE**
	5 - SYNCROCHECK SUPERV.	**1 - SYNC WAIT ENABLE**

- **Recloser: HMI Access (DLX-A Model)**

0 - CONFIGURATION	0 - GENERAL	**0 - IN SERVICE**
1 - OPERATIONS	1 - PROTECTION	**1 - RECLOSERS NUMBER**
2 - ACTIVATE GROUP	**2 - RECLOSER**	**2 - MASTER RECLOSER**
3 - CHANGE SETTINGS	3 - LOGIC	**3 - SLAVE PERMISSION**
4 - INFORMATION	...	**4 - RECLOSER TIMERS**
		5 - SEQ CONTROL TIMER
		6 - SEQUENCE CONTROL
		7 - RECLOSER INIT MASK

Recloser Timers

0 - GENERAL	0 - IN SERVICE	**0 - 1ST 1PH RECL ATTEMPT**
1 - PROTECTION	1 - RECLOSERS NUMBER	**1 - 1ST 3PH RECL ATTEMPT**
2 - RECLOSER	2 - MASTER RECLOSER	**2 - 2ND RECLOS ATTEMPT**
3 - LOGIC	3 - SLAVE PERMISSION	**3 - 3RD RECL. ATTEMPT**
...	**4 - RECLOSER TIMERS**	**4 - 4TH RECL. ATTEMPT**
	5 - SEQ CONTROL TIMER	
	6 - SEQUENCE CONTROL	
	7 - RECLOSER INIT MASK	

Sequence Control Timers

0 - GENERAL	0 - IN SERVICE	**0 - START TIME**
1 - PROTECTION	1 - RECLOSERS NUMBER	**1 - SECURITY TIME**
2 - RECLOSER	2 - MASTER RECLOSER	**2 - SECURITY TIME 2**
3 - LOGIC	3 - SLAVE PERMISSION	**3 - MC RESET TIME**
...	4 - RECLOSER TIMERS	**4 - SYNC WAIT TIME**
	5 - SEQ CONTROL TIMER	
	6 - SEQUENCE CONTROL	
	7 - RECLOSER INIT MASK	

Sequence Control

0 - GENERAL	0 - IN SERVICE	
1 - PROTECTION	1 - RECLOSERS NUMBER	
2 - RECLOSER	2 - MASTER RECLOSER	
3 - LOGIC	3 - SLAVE PERMISSION	
...	4 - RECLOSER TIMERS	**0 - RECLOSING MODE**
	5 - SEQ CONTROL TIMER	**1 - RECLOSE ATTEMPTS**
	6 - SEQUENCE CONTROL	**2 - EXTERNAL BLOCKING**
	7 - RECLOSER INIT MASK	

3.20.12 Digital Inputs and Events of the Recloser

Table 3.20-1: Digital Inputs and Events of the Recloser

Name	Description	Function
IN_EXT_A	A Pole External Trip Input (DLX-B)	Activation of this input indicates the existence of an A pole trip of the breaker generated by an external protection.
IN_EXT_B	B Pole External Trip Input (DLX-B)	Activation of this input indicates the existence of an B pole trip of the breaker generated by an external protection.
IN_EXT_C	C Pole External Trip Input (DLX-B)	Activation of this input indicates the existence of an C pole trip of the breaker generated by an external protection.
IN_EXT_3PH	Three-Phase External Trip Input	Activation of this input indicates the existence of a three-phase trip of the breaker generated by an external protection.
IN_EXT	External Trip Input (DLX-B)	Activation of this input indicates the existence of a trip of the breaker generated by an external protection.
INBLK_MAN	Recloser Manual Block Command	An activation pulse of this input sends the Recloser to the Block Command state.
IN_UNBLK_MAN	Recloser Manual Unblock Command	An activation pulse of this input removes the Recloser from the Block Command state (provided that the External Blocking Type setting is not at level and the BE input is active).
INBLK_EXT	Recloser External Block Command	An activation pulse of this input sends the Recloser to the Block Command state (provided that the External Blocking Type setting is at Pulse).
IN_UNBLK_EXT	Recloser External Unblock Command	An activation pulse of this input removes the Recloser from the Block Command state (provided that the External Blocking Type setting is at Pulse).
RST_NUMREC	Shot Counter Reset Command	Said input resets the two breaker shot counters (single-phase and three-phase)
ENBL_REC	Recloser Enable Input	Activating this input puts the automatic Recloser in operation. They can be assigned to level digital inputs or commands from the communications protocol or the MMI. Default value is “1”.

3.20.13 Digital Outputs and Events of the Recloser

Table 3.20-2: Digital Outputs and Events of the Recloser

Name	Description	Function
RCLS	Recloser Start	Recloser start.
RECLOSING	Reclose Sequence In Progress	Reclose sequence in progress.
RCLS_CMD	Recloser Command	Recloser command.
RCLS_LO	Recloser Lockout	LO_NO_SYNC + LO_DT + LO_CLSF + LO_COF + LO_BF + LO_3PH + LO_OPEN
LO_NO_SYNC	Recloser Lockout due to Lack Of Synchronism	
LO_DT	Recloser Lockout due to Definite Trip	
LO_BF	Recloser Lockout due to Breaker Close Failure	
LO_COF	Recloser Lockout due to Close-Onto-A-Fault	
LO_BF	Recloser Lockout due to Breaker Failure	
LO_3PH	Recloser Lockout due to Three-Phase Trip (DLX-B)	
LO_OPEN	Recloser Lockout due to Open Breaker	
LO_CMD	Recloser Lockout Command	
RESET_C_RNG	Recloser Counters Reset	
BLK_CMD	Recloser Block Command	Recloser block command generated through manual or external block command
UNBLK_CMD	Recloser Unblock Command	Recloser unblock command generated through manual or external block command
ACT_EXTR	External Trip Activation (DLX-B)	Trip indication of any pole of the breaker by external protection.
ACT_EXTR_3PH	External Three-Phase Trip Activation	Trip indication of the three poles of the breaker by external protection.
REC_ENBLD	Recloser Enabled	Automatic reclose function enabled or disabled state signal.
1P	1p Mode Active	Active 1P reclose mode signal.
3P	3p Mode Active	Active 3P reclose mode signal.
1P3P	1p/3p Mode Active	Active 1P/3P reclose mode signal.
DEP	Dep. Mode Active	Active dependent reclose mode signal.
RCLS_STANDBY	Recloser Reset	Signal states Recloser is reset.
IN_EXT_A	A Pole External Trip Input (DLX-B)	The same as for the Digital Inputs.
IN_EXT_B	B Pole External Trip Input (DLX-B)	
IN_EXT_C	C Pole External Trip Input (DLX-B)	
IN_EXT_3PH	Three-Phase External Trip Input	
IN_EXT	External Trip Input (DLX-B)	
INBLK_MAN	Recloser Manual Block Command	
IN_UNBLK_MAN	Recloser Manual Unblock Command	
INBLK_EXT	Recloser External Block Command	
IN_UNBLK_EXT	Recloser External Unblock Command	
RST_NUMREC	Shot Counter Reset Command	
ENBL_REC	Recloser Enable Input	

3.20.14 Recloser Magnitudes

Table 3.20-3: Recloser Magnitudes		
Name	**Description**	**Function**
REE MONO	Single-Phase Shot Counter (DLX-B)	
REE TRIF	Three-Phase Shot Counter	

3.20.15 Recloser Test

For testing the Recloser function, the following is important:

- After a **Manual Closing**, the Reset **Time after a Manual Close** should be awaited. If this time is not allowed to expire before generating the trip, the Recloser will become blocked.
- In order to start the Reclose Sequence, the protection should detect that the breaker is open and that current does not circulate through the phases before concluding the **Sequence Start Time** (setting situated in the **Recloser** - **Sequence Control Time**).
- In order that the Recloser carries out the entire sequence up to the definite trip, the trips should be carried out with a time interval between them shorter than the adjusted **Reset Time**.
- The trip and reclose masks should be considered.

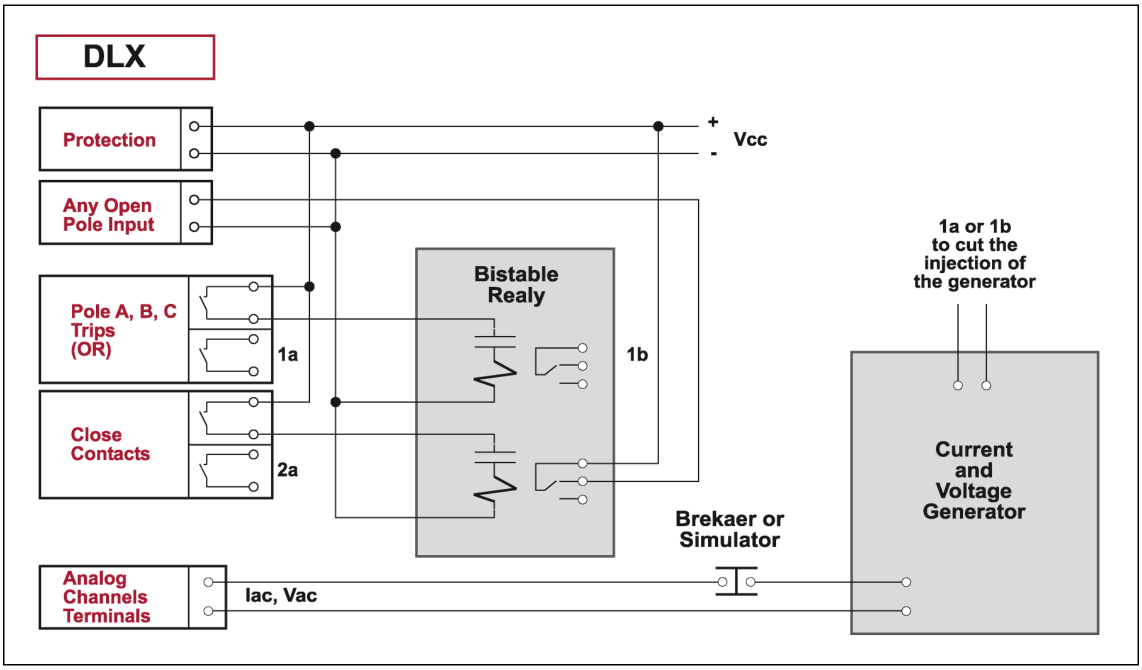

Figure 3.20.9 Connection Diagram for the Recloser Test.

Figure 3.20.9 shows how to perform the Recloser test. If the current generator does not cut off the injection before the sequence check times out, the test can be performed either by opening the current circuit (with the breaker itself or by simulating it), or by causing an instantaneous unit trip with a simple pulse. This may be enough for the instantaneous unit to operate and, at the same time, to cease detecting current before the sequence check times out.

In case that three bistables are available to carry out the test, a trip should be wired to each bistable (A pole, B pole, C pole). Similarly, we will obtain one output from each bistable, which we will wire to the **Open A Pole**, **Open B Pole** and **Open C Pole** inputs (instead of wiring the three to **Any Open Pole**).

Once we have the scheme of Figure 3.20.4 prepared, the following auxiliary outputs will be configured in the manner indicated:

Table 3.20-4:Description of Logic Signal
Recloser Lockout
Recloser Lockout due to Lack Of Synchronism
Recloser Lockout due to Definite Trip
Recloser Lockout due to Breaker Close Failure
Recloser Lockout due to Close-Onto-A-Fault
Recloser Lockout due to Breaker Failure
Recloser Lockout due to Three-Phase Trip
Recloser Lockout due to Open Breaker
Recloser Sequence in Progress
Recloser Blocked
Reclose Signal Activation

During the entire Recloser test, an attempt will be made for there to be synchronism conditions in order that this is not internally lockout due to lack of synchronism.

The breaker will close, waiting longer than the reset time after external closing to continue.

Disable all the auxiliary units not associated with the distance elements, and adjust all the bits of the **Zone Trip Mask** to **NO**, except those corresponding to **Phase Differential**.

Note: The test corresponding to the 3P Mode will be used to test the DLX-A Recloser function models.

- **1P Mode**

Two tests should be performed, corresponding to a first single-phase trip and to a first three-phase trip.

First Single-Phase Trip

Apply an internal fault to phase A. The following events should occur:

1. Trip and activation of the **Recloser Sequence in Progress**.
2. Reclosing on expiration of the single-phase reclose time.

The current will be reapplied prior to the expiration of the **Reset Time**. The following outputs should be activated: the **Recloser Lockout**, the **Recloser Lockout Due to Definite Trip** and the **Recloser Lockout Due to Three-Phase Trip**. The **Recloser Sequence in Progress** output should be deactivated. Once this state has been reached, no subsequent reclose signal should be produced.

Close the breaker. The **Recloser Lockout**, **Recloser Lockout Due to Definite Trip** and **Recloser Lockout Due to Three-Phase Trip** outputs should deactivate after Reset Time.

The Recloser Counter should indicate that the number of single-phase recloses equals **1** and the number of three-phase recloses equals **0**. After viewing the display, reset the counters.

First Three-Phase Trip

Apply an internal fault to A and B phases.

Produce a trip, closing the **Recloser Lockout** and the **Recloser Lockout Due to Three-Phase Trip** contacts.

Close the breaker. The **Recloser Lockout** and **Recloser Lockout Due to Three-Phase Trip** outputs should deactivate after **Reset Time**.

The Recloser Counter should indicate that the number of single-phase reclose attempts equals **0** and the number of three-phase reclose attempts equals **0**.

- **3P Mode**

Set the unit to **3P Mode**. Trips in this mode should always be three-phase. A single test should be performed, corresponding to a first three-phase trip (the fault should be single-phase to ground).

First Three-Phase Trip

Apply an internal fault to phase A.

The following events will occur:

1. Trip and activation of the **Recloser Sequence in Progress** signal.
2. Reclosing (on expiration of the reclose time).

Before the **Reset Time** expires, the current will be reapplied, producing a trip and, on expiration of the time of the 2nd reclosing attempt, a reclosing. The **Sequence in Progress** signal will continue activated.

Before the **Reset Time** expires, the current will be reapplied, producing a trip and, on expiration of the time of the 3rd reclosing attempt, a reclosing. The **Sequence in Progress** signal will continue activated.

Before the **Reset Time** expires, the current will be reapplied, producing a trip and, on expiration of the time of the 4th reclosing attempt, a reclosing. The **Sequence in Progress** signal will continue activated.

Before the Reset Time expires, the current will be reapplied, producing a trip. The **Recloser Lockout** and the **Recloser Lockout Due to Definite Trip** signals should activated; the **Recloser Sequence in Progress** contact should deactivated. Once this state is reached, a subsequent reclosing will not take place.

Close the breaker. The **Recloser Lockout** and **Recloser Lockout Due to Definite Trip** outputs should deactivate after the Reset Time.

The Recloser Counter should indicate that the number of single-phase reclose attempts equals **0** and the number of three-phase reclose attempts equals **4**. After viewing the display, reset the counters.

- **1P/3P Mode**

Set the unit to **1P / 3P Mode**. Two tests should be performed, corresponding to a first single-phase trip and to a first three-phase trip. After each trip, the fault report should contain information regarding the conditions surrounding the trip.

First Single-Phase Trip

Apply an internal fault to phase A. The following events will occur:

1. Trip and activation of the **Recloser Sequence in Progress** signal.
2. Reclosing, on expiration of the single-phase reclose time.

Before the **Reset Time** expires, the current will be reapplied, producing a trip and, on expiration of the time of the 2nd reclosing attempt, a reclosing. The **Sequence in Progress** signal will continue activated.

Before the **Reset Time** expires, the current will be reapplied, producing a trip and, on expiration of the time of the 3rd reclosing attempt, a reclosing. The **Sequence in Progress** signal will continue activated.

Before the **Reset Time** expires, the current will be reapplied, producing a trip and, on expiration of the time of the 4th reclosing attempt, a reclosing. The **Sequence in Progress** signal will continue activated.

Before the **Reset Time** expires, the current will be reapplied. The **Recloser Lockout** and the **Recloser Lockout Due to Definite Trip** signals should activated; the **Recloser Sequence in Progress** contact should deactivated. Once this state is reached, a subsequent reclosing will not take place.

Close the breaker. The **Recloser Lockout** and **Recloser Lockout Due to Definite Trip** outputs should open after the **Reset Time**.

The Recloser Counter should indicate that the number of single-phase reclose attempts equals **1** and the number of three-phase reclose attempts equals **3**. After viewing the display, reset the counters.

First Three-Phase Trip

Apply an internal fault to A and B phases. The following events will occur:

1. Trip and activation of the **Recloser Sequence in Progress** signal.
2. Reclosing, on expiration of the first three-phase reclose time.

Before the Reset Time expires, the current will be reapplied, producing a trip and, on expiration of the time of the 2nd reclosing attempt, a reclosing. The **Sequence in Progress** signal will continue activated.

Before the Reset Time expires, the current will be reapplied, producing a trip and, on expiration of the time of the 3rd reclosing attempt, a reclosing. The **Sequence in Progress** signal will continue activated.

Before the Reset Time expires, the current will be reapplied, producing a trip and, on expiration of the time of the 4th reclosing attempt, a reclosing. The **Sequence in Progress** signal will continue activated.

The current will be reapplied before the **Reset Time** expires. The **Recloser Lockout** and the **Recloser Lockout Due to Definite Trip** signals should activate; the **Recloser Sequence in Progress** signal should deactivate. Once this state reached, a subsequent reclosing will not take place.

Close the breaker. The **Recloser Lockout** and **Recloser Lockout Due to Definite Trip** (**AUX7**) signals should deactivate once the Reset Time has expired.

The Recloser Counter should indicate that the number of single-phase reclose attempts equals **0** and the number of three-phase reclose attempts equals **4**. After viewing, reset the counters.

- **Dependent Mode**

Set the unit to the **Dependent Mode**. Two tests should be performed, corresponding to a first single-phase trip and to a first three-phase trip. After each trip, the fault report should contain information regarding the conditions surrounding the trip.

First Single-Phase Trip

Apply an internal fault to phase A. The following events will occur:

1. Trip and activation of the **Recloser Sequence in Progress** signal.
2. Reclosing, on expiration of the single-phase reclose time.

Before the Reset Time expires, the current will be reapplied, producing a trip and, on expiration of the time of the 2nd reclosing attempt, a reclosing. The **Sequence in Progress** signal will continue activated.

Before the Reset Time expires, the current will be reapplied, producing a trip and, on expiration of the time of the 3rd reclosing attempt, a reclosing. The **Sequence in Progress** signal will continue activated.

Before the Reset Time expires, the current will be reapplied, producing a trip and, on expiration of the time of the 4th reclosing attempt, a reclosing. The **Sequence in Progress** signal will continue activated.

Before the **Reset Time** expires, the current will be reapplied. The **Recloser Lockout** and the **Recloser Lockout Due to Definite Trip** signals should activate; the **Recloser Sequence in Progress** contact should deactivated. Once this state is reached, a subsequent reclosing will not take place.

Close the breaker. The **Recloser Lockout** and **Recloser Lockout Due to Definite Trip** outputs should open after the **Reset Time**.

First Three-Phase Trip

Apply an internal fault to A and B phases. The following events will occur:

1. Trip and activation of the **Recloser Sequence in Progress** signal.
2. Reclosing, on expiration of the first three-phase reclose time.

Before the **Reset Time** expires, the current will be reapplied. The **Recloser Lockout** and the **Recloser Lockout Due to Definite Trip** signals should activate. **The Recloser Sequence in Progress** signal should deactivate. Once this state reached, a subsequent reclosing will not take place.

The breaker will close. **Recloser Lockout** and the **Recloser Lockout Due to Definite Trip** outputs should deactivate 3 seconds later.

The Recloser Counter should indicate that the number of single-phase reclose attempts equals **0** and the number of three-phase reclose attempts equals **1**. Reset the counters.

3.21 Command Logic

3.21.1	Introduction	3.21-2
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3.21.6	Digital Outputs and Events of the Command Logic Module	3.21-6

3.21.1 Introduction

The **DLX** IED presents a command logic in charge of generating the open command outputs of each pole of the breaker (**OPEN_A**, **OPEN_B** and **OPEN_C**), in addition to the open outputs (**OPEN**) and three-phase open (**OPEN_3PH**), from the trip commands (originating from the Tripping Logic) and manual open (**Manual Open Command** input: **IN_OPEN_CMD**). Similarly, the command module is in charge of generating the close output of the breaker (**CLOSE**) from the reclose (**RCLS_CMD**) and manual close (**Manual Close Command** input: **IN_CLOSE_MAN**) commands.

On the other hand, the command module allows to generate the **Open Command Failure** signals of each pole of the breaker (**FAIL_OPEN_A**, **FAIL_OPEN_B** and **FAIL_OPEN_C**) and **Close Command Failure** (**FAIL_CLS**), from the previously-mentioned open / close outputs

The following functions exist within the Command Logic group: **Trip Seal-in Enable**, **Breaker Opening / Closing Failure Time Delay**, **Close supervision by Synchronism Check** and **Pickup Report**.

3.21.2 Opening Command

3.21.2.a Opening Command Logic. DLX-B Models

The opening command generation logic is shown in Figures 3.21.1 and 3.21.2.

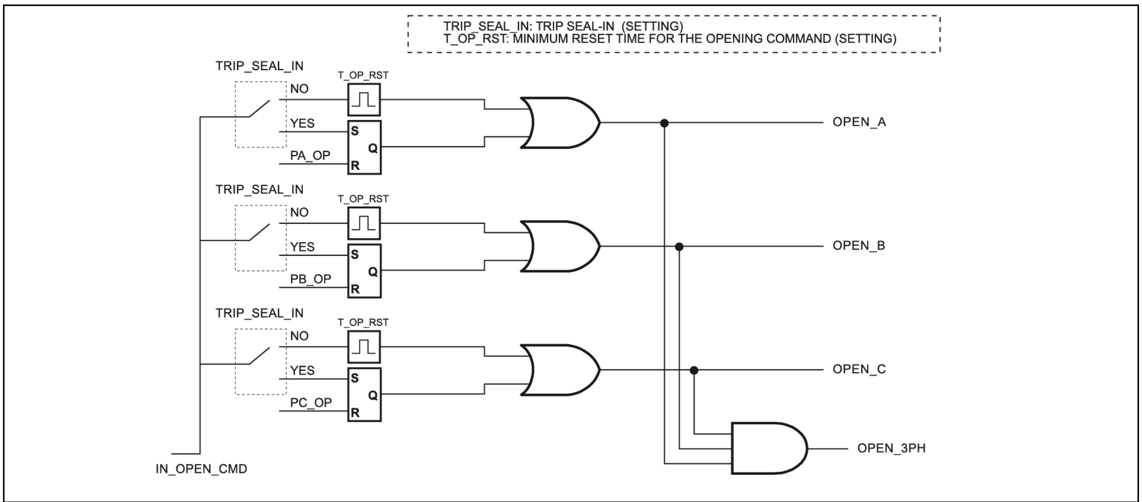

Figure 3.21.1 Logic Diagram of Generation of Opening Commands from a Manual Command (DLX-B).

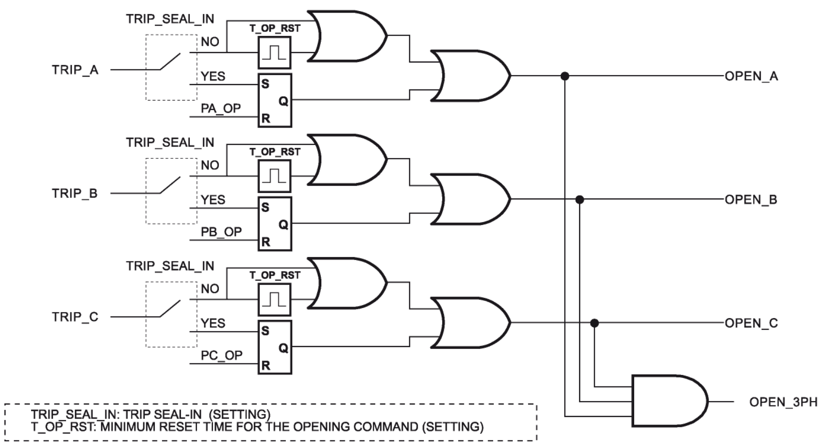

Figure 3.21.2 Logic Diagram of Generation of Opening Commands from Trip Commands (DLX-B).

The Trip Seal-In function is enabled by providing the **Seal-In Enable** setting with the **YES** value. Under these circumstances, the opening command over a pole of the breaker (**OPEN_A**, **OPEN_B** and **OPEN_C**) will be kept activated as long as the opening of this is not detected (**PA_OP**, **PB_OP** and **PC_OP** open pole detector outputs). The objective of this setting is to ensure that the break contacts of the relay do not cut the current of the trip circuit of the breaker poles, given that this operation will be carried out by the corresponding 52/a auxiliary contact of the breaker. The relay contacts may be damaged on cutting the trip circuit current, since this current (basically inductive and of a high value) tends to exceed the rated break characteristics of these contacts.

Although the **NO** value is assigned to the **Seal-in Enable** setting, if the opening command originates from trip outputs, it should be considered that these outputs remain activated until the supervision units are reset, which already produces a seal. On the other hand, in the command logic, for manual operations as well as trip commands, a time is guaranteed for the opening command, configurable according to the **T_OP_RST** setting (**Minimum Reset Time from the Open Command**):

- If the activation of the opening command is preceded by a trip signal that is deactivated before the **T_OP_RST** time, the opening command will last during the set time. If the activation of the trip signal lasts longer than the **T_OP_RST** setting, the opening command will stay until the trip condition clears.
- If the activation of the opening command precedes a manual opening command, its duration is always a pulse defined by the **T_OP_RST** time.

Only if the trip **Seal-in Enable** setting is set at **YES** will the opening command be maintained for the necessary time until the breaker open is shown.

Once the opening command of a pole of the breaker is generated, if the **Opening Command Failure Time** setting elapses without detecting the open status of the pole, the **Opening Command Failure** output of this pole (**FAIL_OPEN_A**, **FAIL_OPEN_B** and **FAIL_OPEN_C**) is activated, in addition to the **Opening Command Failure** (**FAIL_OPEN**) generic output.

3.21.2.b Opening Command Logic. DLX-A Models

Open command logics are shown in figures 3.21.3 and 3.21.4:

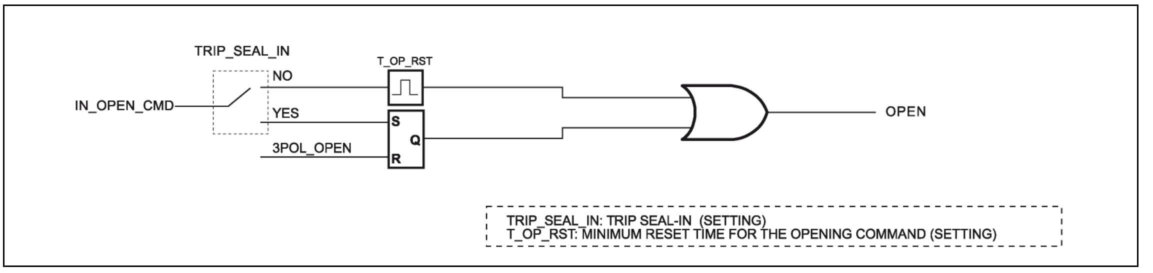

Figure 3.21.3 Open Command Generation Logic Diagram from Manual Command (DLX-A).

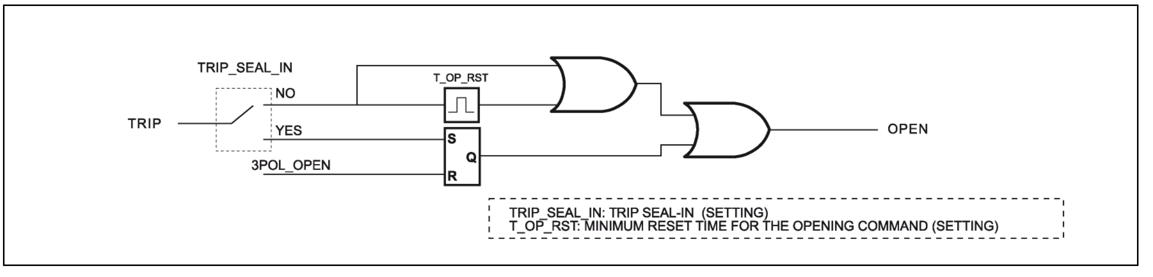

Figure 3.21.4 Open Command Generation Logic Diagram from Trip Command (DLX-A).

Once the opening command of the breaker is generated, if the **Opening Command Failure Time** setting elapses without detecting the opening of the breaker, the **Opening Command Failure** output is activated.

3.21.3 Closing Commands

The **Close** output (**CLOSE**) will be generated by the **Reclose Command** (**RCLS_CMD**) or by the **Manual Close Command** (**IN_CLOSE_MAN**). The latter close command may be supervised by the existence of synchronism. For this, it is necessary that the close **Supervision Due to Synchronism** setting (**SUP_C_SINC**) be set at **YES**.

The **Close Command** output will be disabled on the following conditions:

- **Close Block** input activation.
- **Open Command** output activation.
- All breaker poles closed.

Once the close command of the breaker is generated, if the **Closing Command Failure** time setting elapses without detecting the closing of the breaker (no pole open: **OR_P_OP** at zero) the **Closing Command Failure** (**FAIL_CLS**) output is activated.

The **Close** output will be maintained until it is detected that the breaker has closed or until the **Close Command Failure** is issued.

The **Close** output will remain active at least the **Minimum Reset Time for Closing** (**T_CL_RST** setting). In addition, if the breaker fails to close, this time could be prolonged until the Failure of the **Closing Command** is given (provided that this time is longer than the **T_CL_RST** setting).

In case of protection trips, the **Opening Command** will remain as long as the reason for which this originated continues, even if the **Opening Failure Time** is exceeded.

3.21.4 Command Logic Settings

Command Logic Settings			
Setting	**Range**	**Step**	**By default**
Trip Seal-In Enable	YES / NO		NO
Minimum Reset Time for the Opening Command	0.1 - 5 s	0.1 s	0.2 s
Breaker Opening Failure Time Delay	0.02 - 5 s	0.01 s	0.02 s
Minimum Reset Time for the Closing Command	0 - 5 s	0.1 s	0.2 s
Breaker Closing Failure Time Delay	0.02 - 5 s	0.01 s	0.02 s
Breaker Closing Synchrocheck Supervision	YES / NO		NO
Pickup Report	YES / NO		NO

- **Command Logic: HMI Access**

0 - CONFIGURATION	0 - GENERAL	**0 - TRIP SEAL-IN**
1 - OPERATIONS	1 - PROTECTION	**1 - MIN OPENING RES T**
2 - ACTIVATE GROUP	2 - RECLOSER	**2 - FAIL TO OPEN TIME**
3 - CHANGE SETTINGS	**3 - LOGIC**	**3 - MIN CLOSING RES T**
4 - INFORMATION	...	**4 - FAIL TO CLOSE TIME**
		5 - PICK UP REPORT
		6 - SYNCR. SUPERVISION

3.21.5 Digital Inputs and Events of the Command Logic Module

Table 3.21-1: Digital Inputs and Events of the Command Logic Module		
Name	**Description**	**Function**
IN_BLK_CLS	Breaker Close Blocking Input	Its activation blocks close output.
IN_OPEN_CMD	Manual Opening Command	Its activation generates manual open and close commands, respectively; these can be assigned to HMI, to communications, to digital inputs or to any signal of the programmable logic. Its application is directed toward being assigned to COMMANDS.
IN_CLOSE_CMD	Manual Closing Command	

3.21.6 Digital Outputs and Events of the Command Logic Module

Table 3.21-2: Digital Outputs and Events of the Command Logic Module		
Name	**Description**	**Function**
OPEN	Open Command	Open
OPEN_A	A Pole Open Command (DLX-B)	A pole open output of the breaker.
OPEN_B	B Pole Open Command (DLX-B)	B pole open output of the breaker.
OPEN_C	C Pole Open Command (DLX-B)	C pole open output of the breaker.
OPEN_3PH	Three-Phase Open Command (DLX-B)	Three-phase open output of the breaker.
CLOSE	Close	Close output of the breaker.
FAIL_OPEN	Open Command Failure	Activated from when the open or close commands are issued, the adjusted times elapse, but these are not carried out.
FAIL_OPEN_A	A Pole Open Command Failure (DLX-B)	
FAIL_OPEN_B	B Pole Open Command Failure (DLX-B)	
FAIL_OPEN_C	C Pole Open Command Failure (DLX-B)	
FAIL_CLS	Close Command Failure	
IN_BLK_CLS	Breaker Close Blocking Input	The same as for de Digital Inputs.
IN_OPEN_CMD	Manual Opening Command	The same as for de Digital Inputs.
IN_CLOSE_CMD	Manual Closing Command	

3.22 Configuration Settings

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3.22.1 Introduction

The following setting groups are included into the Configuration group: **Nominal Values**, **Access Passwords**, **Communications**, **Date and Time**, **Display Controls** and **Command Buttons**.

3.22.2 Nominal Values (Operation Mode)

Nominal operating values are selected through Operating Mode settings, both for current and voltage. Following parameters can be selected:

- **Nominal Phase Current**.
- **Nominal Ground Current**.
- **Nominal Sensitive Ground Current**.
- **Nominal Polarization Ground Current**.
- **Voltage**: (for models with voltage measurement) nominal phase-to-phase voltage setting is the reference value for all settings expressed in times or % *nominal voltage*. Applied both to phase and synchronism voltage.
- **Nominal Frequency**: to select system nominal frequency, regardless whether the frequency adaptation system is later capable of adjusting to changes produced in this magnitude.

After modification of any of the settings above, only accessible from HMI display, relay resets the same as if it were switched off and then switched on; no setting or information is lost.

3.22.3 Access Passwords

The **Passwords** option allows changing access passwords for options: Configuration, Operations and Settings.

Select the Configuration option to change access password for configuration group options. Also, different passwords can be configured for operations and settings modification options.

3.22.4 Communications

See paragraph 3.34 on Communications.

3.22.4.a Local Time Zone Setting

If **Time Zone IRIG-B** is set to **UTC**, a time correction must be introduced to adapt the relay to the local time zone. Setting **Local Time Zone** allows putting UTC time forward or back as required.

3.22.4.b Summer Time / Winter Time Change

Relay allows configuring the dates when summer time / winter time change takes place. In the first case the relay clock is put one hour forward (+1 Hour). In the second case the relay clock is put one hour back (-1 Hour) for the winter season.

To configure a change of season the following must be specified:

- **Begin Time**: time when change of season takes place. Range 0 to 23 h.
- **Begin Day Type**: type of day when change of season takes place. It can take the following values **First Sunday**, **Second Sunday**, **Third Sunday**, **Fourth Sunday**, **Last Sunday** of the month and **Specific Day**.
- **Begin Day**: in case **Specific Day** is selected, state in which specific day of the month the change of season takes place.
- **Begin Month**: state the month in which the change of season takes place.

These settings are independent for the summer and winter seasons.

Note: if the Begin Day setting value is higher than the number of days of a given month, the last valid day of said month is taken as the day for the change of season.

The change of season function can be activated or deactivated through **Summer Time / Winter Time Change Enable** setting.

3.22.5 Display Controls

This setting modifies the display contrast value (high value = more contrast).

3.22.6 Command Buttons

Enables or disables front pushbuttons for performing operations associated to them through the relay programmable logic.

3.22.7 Configuration Settings

Nominal Values			
Setting	**Range**	**Step**	**By Default**
Nominal IABC	1 A / 5 A		5 A
Nominal IG	1 A / 5 A		5 A
Nominal IPOL	1 A / 5 A		5 A
Nominal VABC	50 - 230 V		110 V
Nominal Freq.	50 Hz / 60 Hz		50 Hz

Passwords
The factory-specified access password (full access) is 2140. Nevertheless, you can change the password to access the following options with the keypad: **Configuration**, **Operations** and **Settings**.

Communications
See 3.34

Contrast
Adjustable from the keypad

Date and Time			
Setting	**Range**	**Step**	**By Default**
Local Time Zone	GMT+(0, 1, 2, 3, 3:30, 4, 4:30, 5, 5:30, 5:45, 6, 6:30, 7, 8, 9, 9:30, 10, 11, 12) GMT-(1, 2, 3, 3:30, 4, 5, 6, 7, 8, 9, 9:30, 10, 11)		GMT+01:00
Summer Time / Winter Time Change Enable	YES / NO		NO
Summer Begin Time	0 - 23 Hours	1	2
Summer Begin Day Type	0 = Specific day 1 = First Sunday of the month 2 = Second Sunday of the month 3 = Third Sunday of the month 4 = Fourth Sunday of the month 5 = Last Sunday of the month		Last Sunday of the month
Summer Begin Day	1 - 31	1	1
Summer Begin Month	January, February, March, ...	1	March
Winter Begin Time	0 - 23 Hours	1	3
Winter Begin Day Type	0 = Specific day 1 = First Sunday of the month 2 = Second Sunday of the month 3 = Third Sunday of the month 4 = Fourth Sunday of the month 5 = Last Sunday of the month		Last Sunday of the month
Winter Begin Day	1 - 31	1	1
Winter Begin Month	January, February, March, ...	1	October

- **Configuration Settings: HMI Access**

Nominal Values. DLX-A Model

0 - CONFIGURATION	**0 - NOMINAL VALUES**	**0 - NOMINAL IABC**
1 - OPERATIONS	1 - PASSWORDS	**1 - NOMINAL IG**
2 - ACTIVATE GROUP	2 - COMMUNICATIONS	**2 - NOMINAL ISG**
3 - CHANGE SETTINGS	3 - TIME AND DATE	**3 - NOMINAL FREQ.**
4 - INFORMATION	4 - DISPLAY CONTROLS	
	5 - COMMAND BUTTONS	

Nominal Values. DLX-B Model

0 - CONFIGURATION	**0 - NOMINAL VALUES**	**0 - NOMINAL IABC**
1 - OPERATIONS	1 - PASSWORDS	**1 - NOMINAL IG**
2 - ACTIVATE GROUP	2 - COMMUNICATIONS	**2 - NOMINAL ISG**
3 - CHANGE SETTINGS	3 - TIME AND DATE	**3 - NOMINAL IPOL**
4 - INFORMATION	4 - DISPLAY CONTROLS	**4 - NOMINAL VABC**
	5 - COMMAND BUTTONS	**5 - NOMINAL FREQ.**

Passwords

0 - CONFIGURATION	0 - NOMINAL VALUES	**0 - CONFIGURATION**
1 - OPERATIONS	**1 - PASSWORDS**	**1 - OPERATIONS**
2 - ACTIVATE GROUP	2 - COMMUNICATIONS	**2 - SETTINGS**
3 - CHANGE SETTINGS	3 - TIME AND DATE	
4 - INFORMATION	4 - DISPLAY CONTROLS	
	5 - COMMAND BUTTONS	

Communications

0 - CONFIGURATION	0 - VALORES NOMINALES	**0 - PORTS**
1 - OPERATIONS	1 - PASSWORDS	**1 - PROTOCOLS**
2 - ACTIVATE GROUP	**2 - COMMUNICATIONS**	
3 - CHANGE SETTINGS	3 - TIME AND DATE	
4 - INFORMATION	4 - DISPLAY CONTROLS	
	5 - COMMAND BUTTONS	

Date and Time

0 - CONFIGURATION	0 - VALORES NOMINALES	0 - TIME AND DATE
1 - OPERATIONS	1 - PASSWORDS	1 - LOCAL TIME ZONE
2 - ACTIVATE GROUP	2 - COMMUNICATIONS	2 - SUMMER/WINTER ENAB
3 - CHANGE SETTINGS	3 - TIME AND DATE	3 - SUMMER START HOUR
4 - INFORMATION	4 - DISPLAY CONTROLS	4 - TYPE OF SUMMER DAY
	5 - COMMAND BUTTONS	5 - SUMMER STARTINGDAY
		6 - SUMMER START MONTH
		7 - WINTER START HOUR
		8 - TYPE OF WINTER DAY
		9 - WINTER STARTINGDAY
		10 - WINTER START MONTH

3.23 General Settings

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3.23.1 Introduction

The following settings are included within the General Settings group: Unit in Service, Transformer Ratios, Phase Sequence and Number of Voltage Transformers.

3.23.2 Unit in Service

Relay enabled (**YES**), means that all relay functions work normally (dependent on function settings).

If relay is disabled (**NO**), all functions are restricted to measurement operations only. Measurements are visualized on display and through local and remote communications.

3.23.2.a Auxiliary Outputs and Events (Protection in Service)

Table 3.23-1: Auxiliary Outputs and Events (Protection In Service)

Name	Description	Function
PROT_INSRV	Protection in service	Indicates that the IED is working with all the functions available.

3.23.3 Transformer Ratios

Transformer ratio defines how analog values are displayed on the protection display. If transformer ratio is set to 1, secondary values are displayed. If, on the other hand, the transformer ratio corresponding to analog input adapter transformer is selected, primary values are displayed. Settable turn ratios are:

- Phase, ground, sensitive ground, polarization ground, isolated ground currents (as per model)
- Phase, synchronism and ground voltage (as per model)

Differential Units take into account, when it comes to scaling currents, apart from the local phase current transformation ratio, the remote phase current ratio, which must also be set.

In all cases, all overcurrent and overvoltage protection element settings are referred to secondary values. Programmable logic analog settings could refer both to secondary and primary values.

3.23.4 Input Transducers

Depending on the relay model, input current transducers are included. Depending of the HW, the following converter options can be selected: 0 to 5mA, -2.5 to +2.5 mA or 4 to 20 mA.

It is through the Programmable Logic that the converter can be allocated with a magnitude and a constant to represent the true reading (current, voltage, power,...) and the transformation ratio. The measured current in mA is turned into the actual measured magnitude and shown on the display (V, A, W,...).

3.23.4.a Models with Power Supply Voltage Monitoring

In models incorporating Power Supply Voltage Monitoring function, the relay is provided with a specific HW that allows direct current measurements. Two types of transducers exist depending on nominal voltage of the digital inputs:

- For 24Vdc and 48Vdc digital input relays.
- For 125Vdc and 250Vdc digital input relays

The measured magnitude is available for display and recording in all functions using "user magnitudes" (HMI, ***ZivercomPlus***®, Oscillograms, Events, Logs, Programmable Logic, Protocols,...).

3.23.5 Phase Sequence

Power system phase sequence (ABC or ACB) can be selected in order to:

- Adequately calculate sequence components.
- Select correct directional element polarization magnitudes.
- Select the angle between side A and side B voltages of Synchronism Element.

The **Phase Sequence** setting tells the relay the actual system rotation and all functions operate correctly if analogue current and voltage connections are the same as indicated for A, B and C phases in the external connection scheme.

3.23.6 Number of Voltage Transformers

Models **DLX-B** incorporate **Number of Voltage Transformers** setting to adapt the measuring mode for connection to 3 voltage transformers (phase to ground voltage) or two voltage transformers (AB and BC Phase to Phase Voltage).

If it is configured for **3 transformers**, magnitudes directly calculated from currents and voltages (Power P, Q and S) are figured out as follows:

$$\overline{S} = \frac{\overline{Va} \cdot \overline{Ia}^{*}}{2} + \frac{\overline{Vb} \cdot \overline{Ib}^{*}}{2} + \frac{\overline{Vc} \cdot \overline{Ic}^{*}}{2}$$

Where:

$P = Re(\overline{S})$ $Q = Im(\overline{S})$ and $S = \sqrt{P^2 + Q^2}$

Whereas if the relay is configured for **2 transformers** measuring VAB and VBC phase to phase voltages, the following calculations are made:

- Third phase to phase voltage calculation

$$\overline{V}ca = -(\overline{V}ab + \overline{V}bc)$$

And power calculation

$$\overline{S} = \sqrt{3} \cdot \frac{\overline{U}ab \cdot \overset{*}{\overline{I}a}}{2} \cdot 1\angle -30^{o}$$

P, Q and S values are obtained as above.

For 3-transformer configuration, phase to phase as well as phase angle difference between current and phase to neutral voltage are calculated from phase to ground voltages.

For 2 transformer configuration, phase to ground voltages are calculated as follows:

Based on the fact that local source zero sequence impedance setting (ZSL_0) must be used, the following calculations are made:

- **V_0 Calculation:**

  Calculated from ZS_0 and zero sequence current I_0

$$V_0 = -I_0 * ZS_0$$

  Real and imaginary parts are:

$$Re(V_0) = -[Re(I_0) \cdot ZS_0 \cdot cos(Arg\_ZS_0) - Im(I_0) \cdot ZS_0 \cdot sen(Arg\_ZS_0)]$$
$$Im(V_0) = -[Re(I_0) \cdot ZS_0 \cdot sen(Arg\_ZS_0) + Im(I_0) \cdot ZS_0 \cdot cos(Arg\_ZS_0)]$$

- **Calculation of Phase to Ground Voltages from Phase to Phase Voltages:**

  Phase to ground voltages are calculated from phase to phase voltages and zero sequence voltage

  B-phase voltage

$$Re(V_B) = \frac{3 \cdot Re(V_0) - Re(V_{AB}) + Re(V_{BC})}{3}$$
$$Im(V_B) = \frac{3 \cdot Im(V_0) - Im(V_{AB}) + Im(V_{BC})}{3}$$

  A-phase voltage

$$Re(V_A) = Re(V_{AB}) + Re(V_B)$$
$$Im(V_A) = Im(V_{AB}) + Im(V_B)$$

  C-phase voltage

$$Re(V_C) = Re(V_B) - Re(V_{BC})$$
$$Im(V_C) = Im(V_B) - Im(V_{BC})$$

The rest of calculated magnitudes (PF, Frequency and Energy) are calculated as usual and in the same way for 2 and 3 transformers.

3.23.6.a Information on Magnitudes with 2 or 3 Voltage Transformers

- **On display**

With 2 or 3 voltage transformers the following magnitudes are displayed:

- Phase, ground, sensitive ground and isolated ground if applicable, all with their angles.
- Three sequence currents
- Three phase voltages and synchronism voltage with their angles
- Three phase to phase voltages
- Power, power factor and frequency
- Energy

- **Oscillographic recording**

With 3 voltage transformers the following analog magnitudes are displayed:

- Three phase currents, one ground, one sensitive ground and isolated ground or polarization current if applicable
- Three phase to ground voltages and synchronism voltage

With 2 transformers the same is saved, except that instead of three phase to ground voltages the two connected phase to phase voltages (Vab and Vbc) are saved.

- **Via communications**

Information on relay-measured magnitudes can be accessed through communication ports, no matter whether set to 2 or 3 transformers.

3.23.7 General Settings

Unit In Service			
Setting	**Range**	**Step**	**By Default**
Unit In Service	YES / NO		NO

Transformation Ratio			
Setting	**Range**	**Step**	**By Default**
Phase CT Ratio	1 - 3000	1	1
Remote Phase CT Ratio	1 - 3000	1	1
Ground CT Ratio	1 - 3000	1	1
Sensitive Ground CT Ratio	1 - 3000	1	1
Polarizing CT Ratio	1 - 3000	1	1
Phase VT Ratio	1 - 4000	1	1
Synchronism VT Ratio	1 - 4000	1	1

Phase Sequence			
Setting	**Range**	**Step**	**By Default**
Phase Sequence	ABC / ACB		ABC

Number of VTs			
Setting	**Range**	**Step**	**By Default**
Number of VTs	2 / 3		3

Transducers			
Setting	**Range**	**Step**	**By Default**
Transducer Type	0: 0 - 5 mA 1: -2.5¸ +2.5 mA		-2.5¸ +2.5 mA

Event Mask (Via Communications)	
Event Mask	YES / NO

- **General Settings: HMI Access. DLX-A Model**

0 - CONFIGURATION	**0 - GENERAL**	**0 - UNIT IN SERVICE**
1 - OPERATIONS	1 - PROTECTION	**1 - PHASE CT RATIO**
2 - ACTIVATE GROUP	2 - RECLOSER	**2 - REM. PHASE CT RATIO**
3 - CHANGE SETTINGS	3 - LOGIC	**3 - GND CT RATIO**
4 - INFORMATION	...	**4 - S.G. CT RATIO**
		5 - PHASE SEQUENCE

- **General Settings: HMI Access. DLX-B Model**

0 - CONFIGURATION	**0 - GENERAL**	**0 - UNIT IN SERVICE**
1 - OPERATIONS	1 - PROTECTION	**1 - PHASE CT RATIO**
2 - ACTIVATE GROUP	2 - RECLOSER	**2 - REM. PHASE CT RATIO**
3 - CHANGE SETTINGS	3 - LOGIC	**3 - GND CT RATIO**
4 - INFORMATION	...	**4 - S.G. CT RATIO**
		5 - POL. CT RATIO
		6 - PHASE VT RATIO
		7 - BUSBAR VT RATIO
		8 - PHASE SEQUENCE
		9 - NUMBER OF VT
		10 - TRANSDUCERS

Transducers

0 - GENERAL	...	
1 - PROTECTION	**10 - TRANSDUCERS**	**0 - I1 TRANSDUCER TYPE**
2 - RECLOSER		
3 - LOGIC		
...		

3.24 Trip and Close Coil Circuit Supervision

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3.24.5 Trip and Close Coil Circuit Supervision Settings 3.24-5

3.24.6 Digital Outputs and Events of the Trip/Close Coil Circuit Supervision Module 3.24-6

3.24.1 Description

This function permits an alarm when an anomalous situation occurs in the breaker's switching circuits: losses of the auxiliary switching power supply voltage or openings in the open and close circuits themselves. Up to three switching circuits can be monitored. Each of them can be set to both breaker positions (open and closed) or only to one of them.

This monitor function can generate three outputs: **Trip Circuit Supervision Failure** (**FAIL_SUPR**), **Switching Circuit Failure 2** (**FAIL_CIR2**) and **Switching Circuit Failure 3** (**FAIL_CIR3**), which the programmable logic can use to activate any of the IED's auxiliary contact outputs, also generating the corresponding events.

The three supervisions are treated separately as independent functions that can be independently set to enabled by means of a setting. Figure 3.42.1 is the block diagram showing the application in the situation of open breaker for two circuits with open and closed monitoring.

Notice that models without I/O expansion module; i.e. basic model, feature circuit supervision just for one coil.

3.24.2 Operation Mode

There are settings for supervising the state of three coils: Trip Coil, Coil 2 and Coil 3. Coils 2 and 3 may be trip or close. Hence their generic name. Nevertheless, one of the 3 coils is identified as trip coil because the activation of its corresponding **Trip Circuit Supervision Failure** (**FAIL_SUPR**) keeps the recloser from moving on to start a reclosure.

Each of the coils has an associated pair of configurable digital inputs for monitoring. They can be paired to **Supervision in 2 States**, which is explained next, or individually to **Supervision in 1 State**. In any case, both modes can be combined for different coils (for example, to monitor the trip coil in open and closed, and coil two only in open).

Table 3.24-1 identifies the status contact inputs that must be used to monitor each of the circuits in **DLX** models in general.

Table 3.24-1: Configuration of Digital Inputs for Supervision		
Monitored Circuit	Supervision in 2 states	Supervision in one state
Trip Coil	IN2	IN2
	IN3	-
Coil 2	IN10	IN10
	IN11	-
Coil 3	IN12	IN12
	IN13	-

All these digital inputs do not need to be configured in advance to perform the coils supervision function. By enabling any of the coils supervision, each pair of digital inputs will be automatically configured as per the table above.

Moreover, to monitor the Trip Coil and Coil 2, a positive must be entered through terminal CS1+, and to monitor coil 3, a positive must be entered through terminal CS2+.

Each of the three coils can be configured as:

1. **No supervision**: The supervision algorithm is not executed and the status contact inputs associated with the supervision of each of the coils are treated as standard status contact inputs.
2. **Supervision in 2 States**: The algorithm is the one indicated by way of example in figure 3.24.1 and explained in section 3.24.3. Basically, an XOR algorithm supervises the state of the switching circuit in open as well as in closed.
3. **Supervision in 1 State**: The algorithm only takes into account the supervision of the coil in the breaker's position configured in the input used for this purpose (IN2, IN10 or IN12). It does not monitor in the other position and therefore can never detect a fault in the coil.

For each of the monitored coils, it is possible to set a time after which, if there is discordance, the failure is activated.

Trip and Close Coil Circuit Supervision is not sensitive to the impedance of the circuits seen from the relay. Its operating principle is based on an injection of current pulses that allows detecting continuity in those circuits. Every second a pulse of 100ms is sent, monitoring that the current circulates though the circuit. Current will not circulate if the auxiliary contact is open or the coil circuit is open

3.24.3 Trip Coil Circuit

In the conditions of figure 3.24.1 (Open Breaker), current pulses are injected through inputs **IN2** and **IN3**.

Because **IN2** is connected to contact **52/b** (closed) current flows through it and this is detected. This current flowing means that the voltage on **IN2** (+) will correspond to the drop of voltage in the coil and then, a too low value to get it activated. Then, **IN2** will not be activated.

There is no current flowing through **IN3** as the contact **52/a** is open. Then, the voltage on **IN3** (+) will almost be the one available on the open circuit and therefore **IN3** will be activated.

Given that the supervision has been programmed for **Supervision in 2 States**, the µController in charge of the management of this supervisory function will send a “0” logic to the main µProcessor and this will set the **FAIL_SUPR** (**Trip Circuit Failure**) signal to “0” logic. In this situation it will be detected that the **IN2** digital input is deactivated and **IN3** is activated.

If the trip coil opens, the input that was deactivated, **IN2**, will activate and **IN3** will remain activated. After the configured reset time for trip circuit failure, the **Trip Circuit Failure** (**FAIL_SUPR**) signal will be given.

If a close or a reclosure occurs while the switching circuit is intact, once the command is executed, the state of the breaker and that of its **52/a** and **52/b** contacts changes. Consequently, the activation or deactivation of inputs **IN2** and **IN3** will invert and the **FAIL_SUPR** output will remain deactivated.

The purpose of the reset time is to compensate for the time gap between the closing of contact **52/a** and the opening of **52/b**. Generally, the **IN2** and **IN3** digital contacts do not change state simultaneously and, therefore, there will be a discordance between the two contacts. This will not modify the state of the **FAIL_SUPR** output as long as its duration is less than the set time.

If a trip occurs with the breaker closed and the breaker opens, inverting the state of contacts **52/a** and **52/b**, the **FAIL_SUPR** signal will not activate regardless of the duration of the trip command. If the breaker does not execute the command and the open command persists longer than the established reset time, the **FAIL_SUPR** signal will activate.

If the switching voltage disappears, the inputs that are energized will de-energize and this will activate both switching circuit failure outputs (**FAIL_SUPR**, **FAIL_CIR2** and **FAIL_CIR3**).

When the supervisory function of the trip coil (**FAIL_SUPR**) detects the rupture of the circuit and, consequently, the impossibility of tripping, the sending of close commands to the breaker through the IED should be impeded, manual as well as from the Recloser.

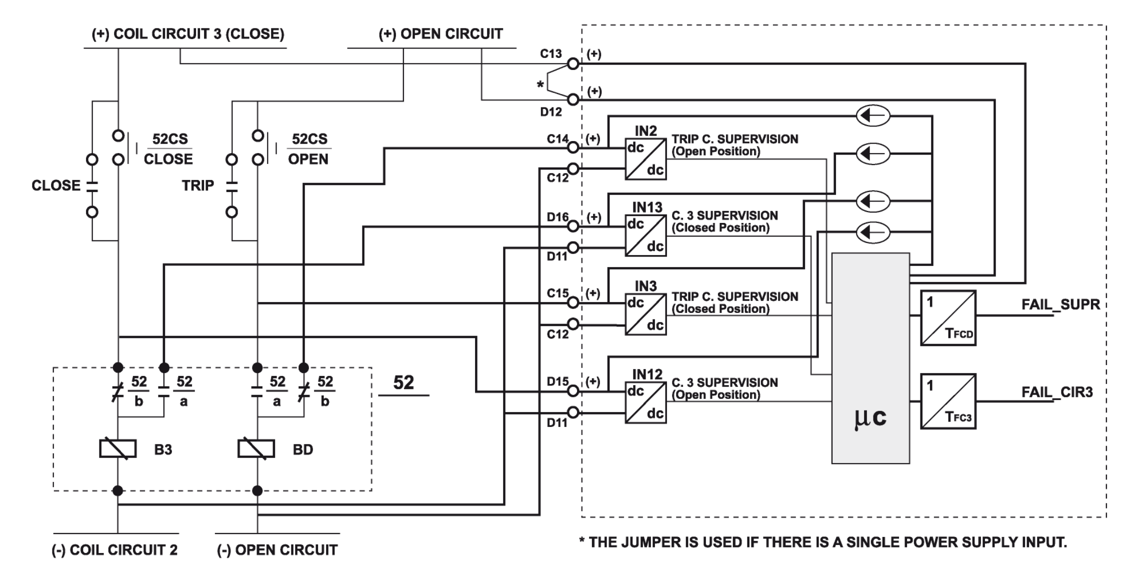

Figure 3.24.1 Trip/Close Coil Circuit Supervision Block Diagram (I).

3.24.4 Coil Circuits 2 and 3

The explanation given for the open circuit is valid for the circuits of coils 2 and 3, referring to a possible close coil and to the corresponding operating circuit and changing the open commands for close commands, or to a second trip coil. Moreover, for coils 2 and 3, the reset times for activating the failure output are independent of that indicated for the open circuit. The failure signal in the switching circuit is called **FAIL_CIR2** and **FAIL_CIR3**.

3.24.5 Trip and Close Coil Circuit Supervision Settings

Trip and Close Coil Circuit Supervision			
Setting	**Range**	**Step**	**By Default**
Trip Coil Supervision	0: NO 1: One State 2: Two States		0: NO
Trip Coil Failure Delay	1 - 60 s	1 s	5 s
Coil 2 Circuit	0: NO 1: One State 2: Two States		0: NO
Coil 2 Failure Delay	1 - 60 s	1 s	5 s
Coil 3 Circuit	0: NO 1: One State 2: Two States		0: NO
Coil 3 Failure Delay	1 - 60 s	1 s	5 s

- **Trip and Close Coil Circuit Supervision: HMI Access. DLX-A Model**

0 - CONFIGURATION	0 - GENERAL	
1 - OPERATIONS	1 - PROTECTION	
2 - ACTIVATE GROUP	...	**0 - TRIP COIL**
3 - CHANGE SETTINGS	**5 - CIRCUIT COIL SUPERV**	**1 - TRIP COIL FAIL. DLY.**
4 - INFORMATION	...	

- **Trip and Close Coil Circuit Supervision: HMI Access. DLX-B Model**

0 - CONFIGURATION	0 - GENERAL	**0 - TRIP COIL**
1 - OPERATIONS	1 - PROTECTION	**1 - CIRCUIT 2 COIL**
2 - ACTIVATE GROUP	...	**2 - CIRCUIT 3 COIL**
3 - CHANGE SETTINGS	**5 - CIRCUIT COIL SUPERV**	**3 - TRIP COIL FAIL. DLY.**
4 - INFORMATION	...	**4 - CIR. 2 COIL FAIL.DLY**
		5 - CIR. 3 COIL FAIL.DLY

3.24.6 Digital Outputs and Events of the Trip/Close Coil Circuit Supervision Module

Table 3.24-2: Digital Outputs and Events of the Trip/Close Coil Circuit Supervision Module

Name	Description	Function
FAIL_SUPR	Trip Circuit Supervision Failure	They activate when an anomaly is detected in one or more of the switching circuits.
FAIL_CIR2	Switching Circuit 2 Failure	
FAIL_CIR3	Switching Circuit 3 Failure	

3.25 Breaker Monitoring

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3.25.1 Breaker Supervision

To have suitable information for performing maintenance operations on the breaker, the **DLX** IED records the interrupting current for each breaker pole and accumulates it as amperes squared. This number is proportional to the accumulated arc energy dissipated by the said breaker pole contacts.

The theoretical formula for the energy of the arc generated during the contact opening process will be: $E_{arc}=\int(I_{arc}*V_{arc})dt$, where I_{arc} and V_{arc} represent arc current and voltage. As $V_{arc}=I_{arc}*R_{arc}$, where R_{arc} is arc resistance, the above formula can be expressed as $E_{arc}=\int(I_{arc}^2*R_{arc})dt$. If a constant arc resistance is assumed, arc energy will be proportional to $I_{RMS}^2*T_{arc}$, where I_{RMS} is the calculated current RMS value during a time frame coinciding exactly with the arc duration and T_{arc} is the duration of the arc between the breaker contacts. **DLX** relays calculate the above expression, with no need for using variable frames (T_{arc} varies from one opening to another), based on the following formula $I_{RMS}^2*T_{window}$, where T_{window}, representing the calculation time frame, is fixed and high enough to cover for arc duration. Based on typical arc durations included in Standard IEC T100a (from 4 to 25 ms), a calculation time frame of 2 cycles has been considered. Said time frame must start at the time when the arc is established between contacts, which can be determined in two ways:

- Taking into account the time when the corresponding Breaker Pole Open signal (whether external or internal to the relay) activates, after adding said pole contact opening time (device operating time: breakers with 2, 3, 5 and 8 cycle operating time have typical contact opening times of 1.5, 2, 3 and 4 cycles).
- Taking into account breaker pole state contact (52b or 52a) operate time after subtracting said contact delay time with respect to the main contacts.

In order to select the most convenient way, based on breaker available information, the arc initiate signal (**Pole X** (X=A, B, C) **Arc Initiate** input) can be configured through the programmable logic (opening signal or breaker state contacts). At the time of activation of said signal, a settable time (**Arc Initiate Delay**: from -1 to 50 cycles in ¼ cycle steps) is added or subtracted.

If neither the contact opening time nor the secondary contact (52b/52a) delay time with respect to the main contacts is known, neither the arc initiate time nor its duration can be calculated. In that case, the best choice is to consider an arc duration of 1 cycle letting the relay store the current RMS value with calculation time frames of equal duration (just setting **Calculation Time Frame** to 1 cycle), starting at the time of breaker pole open signal activation (set **Arc Initiate Delay** to 0 cycles).

DLX relays generate the magnitude **X Pole** (X=A, B, C) **Open Current**. Said magnitude equals the RMS value of the current circulating through breaker n X pole, calculated during the above defined frame. The value of this magnitude updates every time the **X Pole Arc Initiate** input activates, the calculation frame being completed and the **X Pole Open** input activated. The magnitude resets to 0 under various conditions:

- When, after completing the calculation frame, a **X Pole Open Command Failure** occurs (in this case the **X Pole Open** input will not activate). The model **ZLV-H** generates internally the Open Command Failure signals per pole.
- When the **Calculation Frame Duration** setting sets to 0
- When the **Current Buffer Block** input is activated**.** Said input prevents current buffers from increasing (see below) when relays are being checked with secondary injection equipment (during which the breaker current is zero).

Arc energy has been previously considered proportional to $I_{RMS}^2 * T_{arc}$, assuming constant arc resistance. Actually, arc resistance depends on the arc current value, thus arc energy will be proportional to $I_{RMS}^N * T_{arc}$, where N has a value between 1 and 2. The breaker manufacturer as a rule gives two figures of the number of operations at a given current: n1 operations at I1 kA and n2 operations at I2 kA. In order for the energy calculated for both current levels to be the same, an exponent N other than 2 must be used for the current: $n1*I1^N=n2*I2^N$. **DLX** relays have the possibility to select the exponent N through a setting.

DLX relays generate other magnitude, **X** (X=A, B, C) **Pole Opened Current**, which stores the following value, every time the **X Pole Open Current** updates:

$$\left(I_{RMS\_X} \times R_{TIABC}\right)^N \times T_{window}$$

Where I_{RMS_Xn} represents the X pole opened current, R_{TIABC} represents the phase current transformation ratio, N represents the exponent selected and T_{window} represents the selected calculation time frame.

The total stored value is obtained as percentage of the **Stored Current Alarm** setting. When the **X Pole Stored Current** magnitude reaches 100%, the function activates the **X Pole Stored Current** signal that can be used to activate one output through the programmable output function; also a write is added to the event recorder.

The stored current magnitude is updated every time the arc initiate input is activated, nevertheless said magnitude can be modified manually, via **X Pole Stored Current Reset Command** input activation. In that case the latter magnitude will take the value of the **X Pole Stored kA Reset Value** setting. Said setting represents the base stored value above which successive values corresponding to later openings will be added. Manual modification allows taking into account the breaker pole opening history when installing the relay and the updated value after a maintenance operation.

3.25.2 Excessive Number of Trips

The Excessive Number of Trips function is intended to interrupt an uncontrolled sequence of openings and closings that could damage the breaker. When a certain number of trips have occurred, adjustable between 1 and 40 in a definite time period (30 minutes), an output signal is generated and it can be connected to any of the IED's physical auxiliary contact outputs.

The activation of the Excessive Number of Trips output function disables any further reclose initiation by placing the recloser function in the state of **Recloser Lockout Due to Open Breaker** status. This condition will reset only after a manual close command or a loss of auxiliary supply.

3.25.3 Breaker Monitoring Settings

Breaker Monitoring			
Setting	**Range**	**Step**	**By default**
Excessive Number of Trips	1 - 40	1	40
I2 Sum Alarm	0 - 99,999.99 kA^2	0.01	99,999.99
A Pole Cumulative Preset Value I2	0 - 99,999.99 kA^2	0.01	0 kA^2
B Pole Cumulative Preset Value I2	0 - 99,999.99 kA^2	0.01	0 kA^2
C Pole Cumulative Preset Value I2	0 - 99,999.99 kA^2	0.01	0 kA^2
Ka Index	1 - 2	0.1	2
Arc Initiate Delay	(-1) - 50 cycles	¼ cycle	0 cycles
Calculation Frame Duration	0 / 1 / 2 cycles	0.01	2 cycles

- **Breaker Monitoring: HMI Access**

0 - CONFIGURATION	0 - GENERAL	**0 - EXCESSIVE TRIPS**
1 - OPERATIONS	1 - PROTECTION	**1 - I^2 SUM ALARM**
2 - ACTIVATE GROUP	...	**2 - I POLE A DROPOUT**
3 - CHANGE SETTINGS	**4 - BREAKER SUPERV.**	**3 - I POLE B DROPOUT**
4 - INFORMATION	...	**4 - I POLE C DROPOUT**
		5 - KA INDEX
		6 - ARC START DELAY
		7 - WINDOW LENGTH

3.25.4 Digital Inputs and Events of the Breaker Monitoring Module

Table 3.25-1: Digital Inputs and Events of the Breaker Monitoring Module		
Name	**Description**	**Function**
IN_BLK_KA	Current Store Block Input	Activating this input blocks current store.
RST_CUMIA	A Pole Stored Current Reset Command	Activating this input resets A Pole Stored Current magnitude to the “A Pole stored kA reset value” setting.
RST_CUMIB	B Pole Stored Current Reset Command	Activating this input resets B Pole Stored Current magnitude to the “B Pole stored kA reset value” setting.
RST_CUMIC	C Pole Stored Current Reset Command	Activating this input resets C Pole Stored Current magnitude to the “C Pole stored kA reset value” setting.
IN_KA_STR_A	Arc Pole A Start Input	The activation of this input starts the window calculating the RMS current value open by the A pole of the breaker.
IN_KA_STR_B	Arc Pole B Start Input	The activation of this input starts the window calculating the RMS current value open by the B pole of the breaker.
IN_KA_STR_C	Arc Pole C Start Input	The activation of this input starts the window calculating the RMS current value open by the C pole of the breaker.

3.25.5 Digital Outputs and Events of the Breaker Monitoring Module

Table 3.25-2: Digital Outputs and Events of the Breaker Monitoring Module

Name	Description	Function
EXC_NTRIP	Excessive Number of Trips	Indication that the maximum number of trips set has been reached.
AL_KA_A	Pole A Accumulated Amps Alarm	Indication that the kA^{N}* cycles accumulated by pole A of the breaker have reached the alarm level.
AL_KA_B	Pole B Accumulated Amps Alarm	Indication that the kA^{N}* cycles accumulated by pole B of the breaker have reached the alarm level.
AL_KA_C	Pole C Accumulated Amps Alarm	Indication that the kA^{N}* cycles accumulated by pole C of the breaker have reached the alarm level.

3.25.6 Breaker Supervision Module Magnitudes

Table 3.25-3: Breaker Supervision Module Magnitudes

Name	Description	Function
IA ABIERTA	Pole A Opened Current	A
IB ABIERTA	Pole B Opened Current	A
IC ABIERTA	Pole C Opened Current	A
ACUMIAB_A	Pole A Stored Current	KA^{N} x cycle
ACUMIAB_B	Pole B Stored Current	KA^{N} x cycle
ACUMIAB_C	Pole C Stored Current	KA^{N} x cycle

3.26 Change Settings Groups

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3.26.2 Digital Inputs to Change Settings Groups... 3.26-3
3.26.3 Auxiliary Outputs and Events to Change Settings Groups 3.26-4

3.26.1 Description

The Protection, Logic and Recloser settings include four alternative groups (GROUP 1, GROUP 2, GROUP 3 and GROUP 4), which can be activated or deactivated from the keypad, through the communication ports, by using digital inputs or with signals generated in the programmable logic.

This function permits modifying the active setting groups and, thereby, the response of the protection. This way, the behavior of the IED can adapt to changes in the external circumstances.

Two logic input signals can block changes in the active group from the HMI as well as via communications. When inputs **INH_CGRP_COM** and **INH_CGRP_MMI** are active, groups cannot be changed with commands via communications nor through the HMI.

If the digital inputs are used to change groups, up to four digital inputs may need to be configured through the programmable digital inputs:

- Command to activate Settings Group 1 by Digital Input (**CMD_GRP1_DI**)
- Command to activate Settings Group 2 by Digital Input (**CMD_GRP2_DI**)
- Command to activate Settings Group 3 by Digital Input (**CMD_GRP3_DI**)
- Command to activate Settings Group 4 by Digital Input (**CMD_GRP4_DI**)

Activating inputs **CMD_GRP1_DI**, **CMD_GRP2_DI**, **CMD_GRP3_DI** and **CMD_GRP4_DI** will activate GROUP 1, GROUP 2, GROUP 3 and GROUP 4 respectively.

If, while one of the inputs is active, either of the other three or several of them are activated, no group change will take place. The status contact settings group control logic will recognize a single input only. If all four inputs are deactivated, however, the IED will remain in the last active settings group.

Note: Groups can be changed by activating T1, T2, T3 and T4 only if the display is in the default screen.

3.26.2 Digital Inputs to Change Settings Groups

Table 3.26-1: Digital Inputs to Change Settings Groups		
Name	**Description**	**Function**
INH_CGRP_COM	Inhibit Group Change Via Communications	It blocks any change of the active group by the PROCOME procedure.
INH_CGRP_HMI	Inhibit Group Change Via HMI	It blocks any change of the active group through the HMI menu.
CMD_GRP1_COM	Command to Activate Settings Group 1 Via Communications	Commands to change the active group.
CMD_GRP1_DI	Command to Activate Settings Group 1 Via DI	
CMD_GRP1_HMI	Command to Activate Settings Group 1 Via HMI	
CMD_GRP2_COM	Command to Activate Settings Group 2 Via Communications	
CMD_GRP2_DI	Command to Activate Settings Group 2 Via DI	
CMD_GRP2_HMI	Command to Activate Settings Group 2 Via HMI	
CMD_GRP3_COM	Command to Activate Settings Group 3 Via Communications	
CMD_GRP3_DI	Command to Activate Settings Group 3 Via DI	
CMD_GRP3_HMI	Command to Activate Settings Group 3 Via HMI	
CMD_GRP4_COM	Command to Activate Settings Group 4 Via Communications	
CMD_GRP4_DI	Command to Activate Settings Group 4 Via DI	
CMD_GRP4_HMI	Command to Activate Settings Group 4 Via HMI	

3.26.3 Auxiliary Outputs and Events to Change Settings Groups

Table 3.26-2: Auxiliary Outputs and Events to Change Settings Groups

Name	Description	Function
INH_CGRP_COM	Inhibit Group Change Via Communications	The same as for the digital input.
INH_CGRP_HMI	Inhibit Group Change Via HMI	The same as for the digital input.
CMD_GRP1_COM	Command to Activate Settings Group 1 Via Communications	The same as for the digital inputs.
CMD_GRP1_DI	Command to Activate Settings Group 1 Via DI	
CMD_GRP1_HMI	Command to Activate Settings Group 1 Via HMI	
CMD_GRP2_COM	Command to Activate Settings Group 2 Via Communications	
CMD_GRP2_DI	Command to Activate Settings Group 2 Via DI	
CMD_GRP2_HMI	Command to Activate Settings Group 2 Via HMI	
CMD_GRP3_COM	Command to Activate Settings Group 3 Via Communications	
CMD_GRP3_DI	Command to Activate Settings Group 3 Via DI	
CMD_GRP3_HMI	Command to Activate Settings Group 3 Via HMI	
CMD_GRP4_COM	Command to Activate Settings Group 4 Via Communications	
CMD_GRP4_DI	Command to Activate Settings Group 4 Via DI	
CMD_GRP4_HMI	Command to Activate Settings Group 4 Via HMI	
T1_ACTIVATED	Settings Group 1 Activated	Indication of the active group.
T2_ACTIVATED	Settings Group 2 Activated	
T3_ACTIVATED	Settings Group 3 Activated	
T4_ACTIVATED	Settings Group 4 Activated	

3.27 Event Record

3.27.1 Description 3.27-2
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3.27.3 Event Mask.. 3.27-5
3.27.4 Consulting the Record.. 3.27-5
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3.27.6 Event Magnitudes 3.27-6

3.27.1 Description

The capacity of the recorder is 400 notations in non-volatile memory. The signals that generate the events are user-selectable and are recorded with a resolution of 1 ms together with a maximum of 12 values also selectable from all the available metering values measured or calculated by the IED (“user defined values”, including VDC in models with power supply voltage monitoring).

Each of the functions that the system uses records an event in the Event Record when any of the situations listed in the tables nested in the description of each function occurs. Moreover, the events listed in table 3.27-1 -the IED's general services- are also recorded. The tables mentioned above only list the events available with the default configuration. The list of signals can be expanded with those that the user configures in the programmable logic (any signal existing in the programmable logic can be configured to generate an event with the description that the user defines).

Table 3.27-1: Event Record

Name	Description
HMI access	See the description in Auxiliary Outputs.
Clock synchronization	
IRIGB Active	
External oscillography trigger	
Oscillography picked up	
Deletion of oscillographs	
Open command	
Close command	
External trip control	
Trip by Protection	
Open Button	
Close Button	
Blocking / Unblocking Button	
Digital Input 1	
Digital Input 2	
Digital Input 3	
Digital Input 4	
Digital Input 5	
Digital Input 6	

Table 3.27-1: Event Record	
Name	**Description**
Digital Input 7	See the description in Auxiliary Outputs.
Digital Input 8	
Digital Input 9	
Digital Input 10	
Digital Input 11	
Digital Input 12	
Digital Input 13	
Digital Input 14	
Digital Input 15	
Digital Input 16	
Digital Input 17	
Digital Input 18 (*)	
Validity of Digital Input 1	
Validity of Digital Input 2	
Validity of Digital Input 3	
Validity of Digital Input 4	
Validity of Digital Input 5	
Validity of Digital Input 6	
Validity of Digital Input 7	
Validity of Digital Input 8	
Validity of Digital Input 9	
Validity of Digital Input 10	
Validity of Digital Input 11	
Validity of Digital Input 12	
Validity of Digital Input 13	
Validity of Digital Input 14	
Validity of Digital Input 15	
Validity of Digital Input 16	
Validity of Digital Input 17	
Validity of Digital Input 18 (*)	

Table 3.27-1: Event Record	
Name	**Description**
Auxiliary Output 1	See the description in Auxiliary Outputs.
Auxiliary Output 2	
Auxiliary Output 3	
Auxiliary Output 4	
Auxiliary Output 5	
Auxiliary Output 6	
Auxiliary Output 7 (*)	
Leds Reset Input	
Power Meters Reset Input	
Maximeters Reset Command	
Indicator of Current in the Line	
Current Detected with Open Breaker Status	
Cold Load Pickup of IED	
Manual Reinitialization of the IED	
Change of Settings Initialization	
Port 0 Communication Failure	
Port 1 Communication Failure	
Port 2 Communication Failure	
Remote	
Local Control	
Panel-Controlled	
Critical System Error	
Non-Critical System Error	
System Event	
Equipment Warm Start Up	
Maximeters Reset Input	
Distance to the Fault Reset Input	

(*) The number of Digital Inputs and Auxiliary Outputs available will depend on each particular model

All the configured events as well as the pre-existing ones in the default configuration can be masked.

The text indicated in the events tables is expanded with the message **Activation of...** when the event is generated by activation of any of the signals or **Deactivation of...** when the event is generated by deactivation of the signal.

3.27.2 Organization of the Event Record

The event record capacity is 400 events. When the record is full, a new event displaces the oldest one. The following information is stored in each event register:

- Values of the 12 magnitudes selected at the time the event is generated
- Event date and time

Event recorder management is optimized so that simultaneous operations generated by the same event occupy a single position in the event memory. For example, the simultaneous occurrence of the phase A and neutral time overcurrent pickups are recorded in the same memory position. However, if the occurrences are not simultaneous, two separate events are generated. Simultaneous events are those operations occurring within a 1 ms interval, the resolution time of the recorder.

3.27.3 Event Mask

Use the **General** settings in communications to mask unneeded or unused events for system behavior analysis. Events are masked by communications within the **General** settings.

Important: Events that can be generated in excess should be masked since they could fill the memory (400 events) and erase more important previous events.

3.27.4 Consulting the Record

The communications and remote management program, ***ZivercomPlus***®, has a completely decoded system for consulting the Event Record.

3.27.5 Event Record Settings (via communications)

Events Mask
IED events may be masked separately

3.27.6 Event Magnitudes

Table 3.27-2: Event Magnitudes

Name	Description	Units
ACUMIB_A	Pole A Stored Current	KA^N x cycle
ACUMIB_B	Pole B Stored Current	KA^N x cycle
ACUMIB_C	Pole C Stored Current	KA^N x cycle
ALARMAS	Alarm Codes (see 3.36)	
ANG IA	IA Angle	o
ANG IALOC	Local IA Angle (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	o
ANG IAREM	Remote IA Angle (associated to a calculation instant of the differential element; it is updated when a frame with said instant is received from the remote end)	o
ANG IAB	IAB Angle	o
ANG IB	IB Angle	o
ANG IBLOC	Local IB Angle (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	o
ANG IBREM	Remote IB Angle (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	o
ANG IBC	IBC Angle	o
ANG IC	IC Angle	o
ANG ICLOC	Local IC Angle (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	o
ANG ICREM	Remote IC Angle (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	o
ANG ICA	ICA Angle	o
ANG IN	IN Angle	o
ANG INLOC	Local IN Angle (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	o

Table 3.27-2: Event Magnitudes		
Name	**Description**	**Units**
ANG INREM	Remote IN Angle (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	º
ANG INS	IN Angle (Sensitive Ground Current)	º
ANG IPOL	IPOL Angle (Ground Directional Unit Polarization Current)	º
ANG ISD	ISD Angle (Positive Sequence Current)	º
ANG ISDLOC	Local ISD Angle (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	º
ANG ISDREM	Remote ISD Angle (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	º
ANG ISi	ISI Angle (Negative Sequence Current)	º
ANG ISILOC	Local ISI Angle (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	º
ANG ISIREM	Remote ISI Angle (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	º
ANGVA	VA Angle	º
ANGVAB	VAB Angle	º
ANGVAF	VA absolute Angle (Directly generated by DFT)	º
ANGVB	VB Angle	º
ANGVBC	VBC Angle	º
ANGVC	VC Angle	º
ANGVCA	VCA Angle	º
ANGVN	VN Angle	º
ANGVSD	VSD Angle (Positive Sequence Voltage)	º
ANGVSDLOC	Local ISD Angle (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	º
ANGVSDREM	Remote ISD Angle (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	º

Table 3.27-2: Event Magnitudes		
Name	**Description**	**Units**
ANGVSH	VSD Angle (Zero Sequence Voltage)	º
ANGVSI	VSI Angle (Negative Sequence Voltage)	º
ANGVSIN	VSIN Angle (Synchronism Voltage)	º
ARM2 IA	IA 2^{dn} Harmonic Magnitude	A
ARM2 VA	VA 2^{dn} Harmonic Magnitude	V
ARM3 IA	IA 3rd Harmonic Magnitude	A
ARM3 VA	VA 3rd Harmonic Magnitude	V
ARM4 IA	IA 4th Harmonic Magnitude	A
ARM4 VA	VA 4th Harmonic Magnitude	V
ARM5 IA	IA 5th Harmonic Magnitude	A
ARM5 VA	VA 5th Harmonic Magnitude	V
ARM6 IA	IA 6th Harmonic Magnitude	A
ARM6 VA	VA 6th Harmonic Magnitude	V
ARM7 IA	IA 7th Harmonic Magnitude	A
ARM7 VA	VA 7th Harmonic Magnitude	V
ARM8 IA	IA 8th Harmonic Magnitude	A
ARM8 VA	VA 8th Harmonic Magnitude	V
CREENG	Reclose Sequence Number	
CNVI1	Current Transducer 1 value	mA
CorrIncT	Correction of the delay between the clocks of both relays obtained through communications using the GPS	ms
DERFREC	Frequency Rate of Change	Hz / s
DIST	Distance to the fault in %	
DISTk	Distance to the fault km	
DISTm	Distance to the fault in miles	
ERR SEC 1	Number of erroneous seconds in channel 1	
ERR SEC 2	Number of erroneous seconds in channel 2	
FP	Power Factor	
FREC	Frequency (of VA Voltage)	Hz
FREC M IN	Frequency received by the slave relay to adapt the sampling rate (see PLL; only applicable to the slave relay)	Hz
FREC M OUT	Frequency send by the master relay to adapt the sampling rate (see PLL; only applicable to the master relay)	Hz
FREC S	Synchronism Voltage Frequency	Hz

Table 3.27-2: Event Magnitudes		
Name	**Description**	**Units**
IA	IA Magnitude	A
IA DIF	IA DIF Magnitude (Phase A Differential Current)	A
IA FRE	IA FRE Magnitude (Phase A Restraint Current)	A
IA LOC	Local IA Magnitude (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	A
IA REM	Remote IA Magnitude (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	A
IA ABIERTA	Pole A Opened Current	A
IAB	IAB Magnitude	A
IB	IB Magnitude	A
IB DIF	IB DIF Magnitude (Phase B Differential Current)	A
IB FRE	IB FRE Magnitude (Phase B Restraint Current)	A
IB LOC	Local IB Magnitude (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	A
IB REM	Remote IB Magnitude (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	A
IB ABIERTA	Pole B Opened Current	A
IBC	IAB magnitude	A
IC	IC Magnitude	A
IC DIF	IC DIF Magnitude (Phase C Differential Current)	A
IC FRE	IC FRE Magnitude (Phase C Restraint Current)	A
IC LOC	Local IC Magnitude (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	A
IC REM	Remote IC Magnitude (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	A
IC ABIERTA	Pole C Opened Current	A

Table 3.27-2: Event Magnitudes		
Name	**Description**	**Units**
ICA	ICA Magnitude	A
IN DIF	IN DIF Magnitude (Ground Differential Current)	A
IN FRE	IN FRE Magnitude (Ground Restraint Current)	A
IN LOC	Local IN Magnitude (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	A
IN REM	Remote IN Magnitude (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	A
IncT	Delay between the clocks of both relays (master and slave)	ms
IncT M Cong	Historical record saved of the mean delay between the clocks of both relays (master and slave)	ms
IncT Med	Mean delay between the clocks of both relays (master and slave)	ms
INS	INS Magnitude (Sensitive Ground Current)	A
IPOL	IPOL Magnitude (Ground Directional Unit Polarization Current)	A
ISD	ISD Magnitude (Positive Sequence Current)	A
ISD LOC	Local ISD Magnitude (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	A
ISD REM	Remote ISD Magnitude (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	A
ISH	ISH Magnitude (Zero Sequence Current)	A
ISH LOC	Local ISH Magnitude (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	A
ISI	ISI Magnitude (Negative Sequence Current)	A
ISI DIF	ISI DIF Magnitude (Negative Sequence Differential Current)	A
ISI FRE	ISI FRE Magnitude (Negative Sequence Restraint Current)	A
ISI LOC	Local ISI Magnitude (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	A

Table 3.27-2: Event Magnitudes		
Name	**Description**	**Units**
ISI REM	Remote ISI Magnitude (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	A
ITERMICA	Thermal value	%
N.A.ENGY	Negative Active Energy	kWh
N.R.ENGY	Negative Reactive Energy	kVARh
NAPER_A	Number of openings of Pole A	
NAPER_B	Number of openings of Pole B	
NAPER_C	Number of openings of Pole C	
NARRANQS	Number of hot starts (starts due to loss of power supply to the relay)	
NCIERRE	Number of closings	
NINST DIF	Number of the calculation instant received on the remote end frame. It is delayed with respect NINST LOC the time taken to receive the remote messages	
NINST LOC	Number of local calculation instants	
NREARRQS	Number of restarts (starts caused by resets: sending configurations, nominal settings change, etc)	
NTRAPS	Number of traps	
P	Active Power	W
P.A.ENGY	Positive Active Energy	kWh
P.R.ENGY	Positive Reactive Energy	kVARh
PMAX	Maximum Active Power (saved in RAM)	W
PMIN	Minimum Active Power (saved in RAM)	W
Q	Reactive Power	VAR
QMAX	Maximum Reactive Power (saved in RAM)	VAR
QMIN	Minimum Reactive Power (saved in RAM)	VAR
REE MONO	Number of single-phase reclosings	
REE TRIF	Number of three-phase reclosings	
S	Apparent Power	VA
SEV ERR SEC 1	Number of severely erroneous seconds in channel 1	
SEV ERR SEC 2	Number of severely erroneous seconds in channel 2	
SMAX	Maximum Apparent Power (saved in RAM)	VA
SMIN	Minimum Apparent Power (saved in RAM)	VA
TCANAL1	Propagation Time of channel 1	s
TCANAL2	Propagation Time of channel 1	s
TACTIVA	Active Settings Table	
TFALTA	Fault Type (0 = unknown; 1=AN; 2=BN; 3=CN; 4=AB; 5=BC; 6=CA; 7=ABN; 8=BCN; 9=CAN; 10=ABC	
T_FALTA_A	Pole A Operation Time	ms
T_FALTA_B	Pole B Operation Time	ms
T_FALTA_C	Pole C Operation Time	ms

Table 3.27-2: Event Magnitudes		
Name	**Description**	**Units**
TSEG	Time between pulses per second	s
TSEG MED	Mean time between pulses per second	s
VA	VA Magnitude	V
VAB	VAB Magnitude	V
VB	VB Magnitude	V
VBC	VBC Magnitude	V
VC	VC Magnitude	V
VCA	VCA Magnitude	V
VMAX	Maximum Phase Voltage (saved in RAM)	V
VMIN	Minimum Phase Voltage (saved in RAM)	V
VN	VN Magnitude	V
VSD	VSD Magnitude (Positive Sequence Voltage)	V
VSD LOC	Local VSD Magnitude (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	V
VSD REM	Remote VSD Magnitude (associated to a calculation instant of the Differential Element; it is updated when a frame with said instant is received from the remote end)	V
VSH	VSH Magnitude (Zero Sequence Voltage)	V
VSI	VSI Magnitude (Negative Sequence Voltage)	V
VSINC	VSINC Magnitude (Synchronism Voltage)	V

Note: all magnitudes for each event are stored in secondary values; therefore not affected by any primary-to-secondary ratio except for energy magnitudes that are always recorded in primary values.

3.28 Fault Reports

3.28.1 Introduction..3.28-2
3.28.2 Fault Initiation Time Tag...3.28-2
3.28.3 Open Command Time Tag..3.28-2
3.28.4 Fault End Time Tag..3.28-2

3.28.1 Introduction

The terminal incorporates Fault reports register, which stores the most relevant information about faults cleared by the IED. Access to this information is available through the communication ports. The information stored in each fault report is distributed in three tags: **Fault Initiation Time Tag**, **Open Command Time Tag** and **Fault End Time Tag**.

3.28.2 Fault Initiation Time Tag

Presents the date and time of the moment when the activation of the fault detector was produced or, if not activated, the start of the first element involved in the fault. Also included:

- **Pre-fault currents and voltages**. The following currents and voltages are registered two cycles prior to the commencement of the fault (activation of the fault detector or pick up of the first element involved in the fault):

  - Local and remote Phase, Ground and Negative Sequence Currents.
  - Polarization and Sensitive Ground Current.
  - Phase, Ground and Negative Sequence Differential Currents.
  - Phase, Ground and Negative Sequence Restraint Currents.
  - Phase Voltages (Phase and Line)
  - Synchronism Voltage.
  - Local and Remote Positive Sequence Voltages.

  The currents as well as voltages (phase) are accompanied by their arguments.

- **Elements picked up** for full fault duration.

3.28.3 Open Command Time Tag

It presents the date and time of the trip command and also displays:

- **Fault currents and voltages.** The same currents and voltages seen for Fault Initiation Time Tag are registered one and one-half cycle after the pickup of the first element involved in the fault.
- **Trip generator units**, that is, those elements activated at the instant of the trip.
- **Fault Type**.
- **Trip Zone**. Indicates zones involved in the fault.
- **Trip Mode**. Indicates single-phase or three-phase trip.

3.28.4 Fault End Time Tag

It is the date and time of the reset of the last element involved in the fault. Also displays:

- **Fault currents and voltages**.
- **Frequency**.
- **Current interrupted by the breaker**.
- **Thermal state**.
- **Distance to the fault.**

Each record in the fault report includes the setting group active during the trip.

It should be pointed out that the indication of the type of fault will be UNKNOWN FAULT (DES) when all the elements and the trip are reset before the elapse of 1.5 cycles after the first pick up.

3.29 Metering History Log

3.29.1 Operation.. 3.29-2

3.29.2 Metering History Log Settings 3.29-4

3.29.1 Operation

This function records the evolution of the values monitored at the point where the IED is installed. Each second, it samples each of the values programmed for this purpose and calculates their average over the interval defined as **Sampling Interval**. This time interval is adjustable between 1 and 15 minutes.

The **Recording Interval** is an adjustable period of time between 1 minute and 24 hours. The maximum and minimum averages recorded in the whole interval are recorded with their final time stamp. Figure 3.29.1 shows how the Metering History Log works.

-**SI**: Sampling Interval; the figure shows an SI value of one minute.

-**RI**: Recording Interval; the figure shows a RI of 15 minutes.

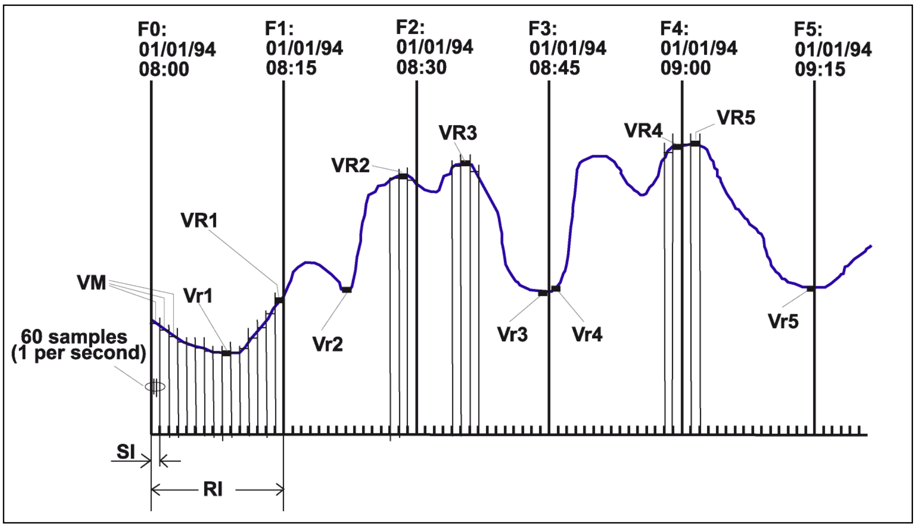

Figure 3.29.1 Explanatory Diagram of the Metering Log.

There are 12 History Log Groups. For each of those 12 values, up to **4 different metering** values can be selected.

Each **SI** window yields two **RI** values that correspond to the maximum and minimum averages of configured group magnitudes. If only one group magnitude is configured, the average value coincides with the maximum and minimum values (see figure 3.28.1). Maximum and minimum value of all maximum and minimum group **VMs** computed are stored and shown in each **RI** interval. The profile of figure 3.29.1 yields the following values: VR1 - Vr1; VR2 - Vr2; VR3 - Vr3; VR4 - Vr4 and VR5 - Vr5.

Note: if phase or ground elements pick up during the Sampling Interval, the average of the measurements made while the elements were not picked up is recorded. Otherwise, if the elements remain picked up throughout the SI, the value recorded is: 0A / 0V.

As already indicated, twelve (12) values can be configured among all the direct or calculated metering values ("user defined values", including VDC in models with power supply voltage monitoring) available in the IED (M_i). For each group, up to four different magnitudes can be selected, an average value being obtained for each magnitude along the **Window for Average Calculation**. See figure 3.29.2.

Thus, for every group (up to 12 groups), maximum and minimum measurements of the different magnitudes (up to 4 magnitudes) in each average interval are calculated. Maximum and minimum values of all maximum and minimum measurements obtained along said interval for each group are recorded in each recording interval.

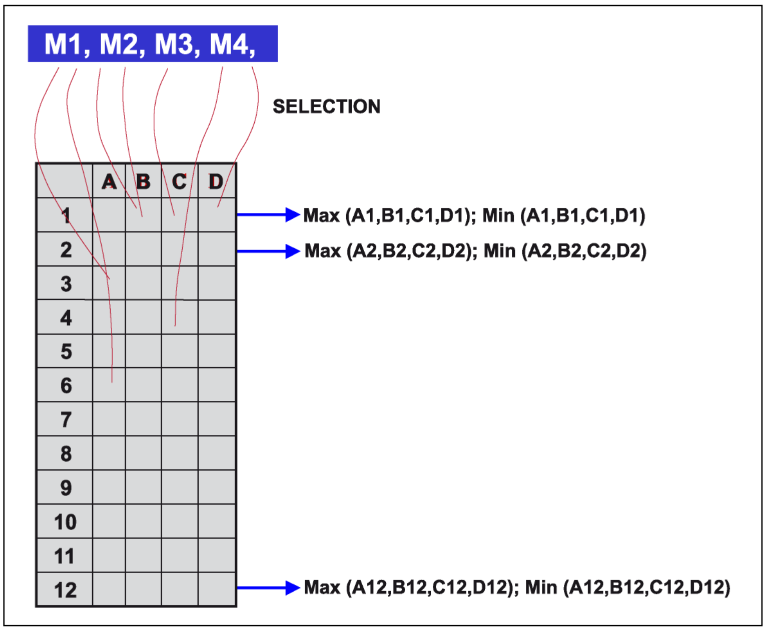

Figure 3.29.2 Metering History Log Logic.

The memory available for the metering log is RAM, large enough for 168 values. The memory can be customized by defining an hour range and **Week Mask** (the same hour range for all the days). No values outside the mask will be recorded.

Likewise, the phase currents and voltages as well as the powers are constantly sampled. The sampled values are compared with those already stored. This keeps a maximum/minimum demand metering of the phase currents and voltages and of the active, reactive and apparent powers up to date.

These maximum and minimum values are stored in non-volatile memory, so they are reset by the logic input signal, **Maximum Demand Element Reset**.

All this information is only available via communications through the communications and remote management program ***ZivercomPlus***®.

3.29.2 Metering History Log Settings

Metering History Log			
Setting	**Range**	**Step**	**By Default**
Sampling Interval	1 - 15 min	1	1 min
Recording Interval	00.00 to 24:00		00:01
Day Calendar Mask	Monday to Sunday	YES / NO	YES
Calendar Time Mask	00.00 to 24:00		00.00

Magnitude Selection
See 3.27, Table 3.27-2.

- **Metering History Log: HMI Access**

0 - CONFIGURATION	0 - GENERAL	**0 - SAMPLE INTERVAL**
1 - OPERATIONS	1 - PROTECTION	**1 - LOG REC. INTERVAL**
2 - ACTIVATE GROUP	...	**2 - HIST. START TIME**
3 - CHANGE SETTINGS	**6 - HISTORY**	**3 - HIST. END TIME**
4 - INFORMATION	...	

3.30 Oscillographic Recording

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3.30.1 Introduction

The Oscillography function is composed of two different sub functions: **Capture** and **Display**. The first captures and stores protection data inside the IED and is part of the relay's software; the second retrieves and presents the stored data graphically with one or more programs running on a PC connected to the protection.

The sampling and storage frequency is 32 samples per cycle with 15 seconds of total storage. Permanence of the information, with the IED disconnected from the power supply, is guaranteed during 28 days at 25º (except for models with long term oscillography where 15 days at 25º are guaranteed).

The IEDs come with a display and analysis program, because the waveform records are in binary COMTRADE format according to IEEE standard C37.111-1999. The COMTRADE file generated considers the changes in frequency that can occur in the system, so that the analog magnitudes are stored with complete fidelity to how they have evolved on the system.

3.30.2 Capture Function

It is possible to record measured analog values, user defined values, digital inputs to the IED, internal logic signals generated by the protection and the programmable logic up to a total of 64 oscillographs in cyclical memory.

3.30.3 Stored Data

The following data are stored with a resolution time equal to the sampling rate:

- Value of the samples of the selected parameters (measured and user defined) and of the digital and analogical signals programmed for this purpose.
- Time stamp of the Oscillography startup.

3.30.4 Number of Channels and Digital Signals

Depending on the model is possible to record up to 15 analog values, enabling or disabling them via independent settings.

It is possible to include up to 5 user defined values. User defined values are every calculated value including those values calculated by the programmable logic via ***ZivercomPlus***®software.

Models with Power Supply Voltage Monitoring measure the voltage via a transducer input. This value is considered an user defined value.

User defined values include any type of parameters. If sine waves are recorded the Oscillography records the changes of the RMS value.

Values are stored in the COMTRADE oscillography format with the label assigned in the programmable logic. The power supply voltage is stored with the label VDC.

It is also possible to assign direct metering from the analog channels as a user defined value. Being waveforms the RMS value is stored. COMTRADE label is VALUE_u (ie. VA_u).

The maximum number of recorded digital signals is 80. Each user defined value configured in the Oscillography counts as 16 digital signals.

3.30.5 Start Function

The start function is determined by a programmable mask applied to certain internal signals (element pickups, open command, etc.) and to an external pickup signal (which, if it is to be used, must be connected to any of the physical status contact inputs, to a programmable button of the HMI, to a command via communications or to a signal configured for this purpose in the programmable logic).

If the start function mask setting is **YES**, this signal activates the Oscillography startup. This signal will not start the Oscillography function if its mask setting is **NO**.

3.30.6 Oscillograph Deletion Function

Since the Oscillograph records are stored in non-volatile memory, there is a mechanism that allows deleting all the content of this memory externally.

The Oscillograph Deletion Function can operate by activating the **Deletion of Oscillographs** signal, which can be assigned by the programmable logic to any of the physical inputs, to a programmable button of the HMI, to a command via communications, etc.).

3.30.7 Trip Required

Data are stored only if a trip occurs within the time configured as Oscillography record length.

3.30.8 Concatenation Stream Mode

The **YES** / **NO** setting allow extending the oscillography record length if new pickups of elements occur while one is being recorded. The recording system restarts the count of sequences to store if any other element picks up before the element generating the oscillography pickup resets.

It is possible for multiple pickups to occur during a fault. Sometimes these pickups are not simultaneous but they are staged in the early moments of a fault. The available memory to store oscillography is divided in zones, depending on the oscillography length setting. To optimize the memory management, pickups occurring during the interval of pickups set of a fault do not extend the length of the oscillography.

3.30.9 Pre-Fault Time

This is the length of pre-fault data that must be stored before the start function initiates a record. The setting range is from 0 to 25 pre-fault cycles.

3.30.10 Length of the Oscillograph

It is the fault record duration. The number of records stored in memory varies and depends on the number of channels recorded and the length of the fault records. Once the recording memory is full, the next event will overwrite the oldest one stored.

The maximum number of waveform records is 64, and the maximum number of cycles that can be stored in memory is 725. Depending on the length selected, the maximum number varies.

Set number of cycles	Max. number of oscillographs
725	1
350	2
175	3
...	...
22	32
11	64

Note 1: when selecting the length of each oscillograph, it is important to take into account that if, for example, an oscillography record length greater than 350 cycles is selected, only one oscillograph can be stored.
Note 2: modifying settings belonging to the oscillography recording or loading a programmable logic configuration will erase all the oscillography files recorded in the IED.

3.30.11 Interval between Triggers

This setting is used to discriminate whether consecutive elements pick-ups correspond to the same fault or not. This way, all activations during that interval would be considered as belonging to the same fault and, therefore, the record is not enlarged

However, for activations after that time, and as long as the **Continuous Mode** setting is enabled, the record will be enlarged as per the **Length of the Oscillograph** setting.

3.30.12 Oscillography Settings

Oscillography			
Setting	**Range**	**Step**	**By Default**
Trip Required	YES / NO		YES
Continuous Mode	YES / NO		NO
Pre-Fault Recording Length	0 - 25 cycles	1	5
Post-Fault Recording Length	5 - 725 cycles	1	5
Interval between Triggers	1 - 725 cycles	1	4

Trigger Mask		
Setting	**Step**	**By Default**
Phase Differential (87 PHASE)	YES / NO	NO
Ground Differential (87 GROUND)	YES / NO	NO
Negative Sequence Differential (87 NEG SEQ)	YES / NO	NO
Internal Fault by Phase Directional Comparison	YES / NO	NO
Internal Fault by Ground Directional Comparison	YES / NO	NO
Internal Fault by Negative Sequence Directional Comparison	YES / NO	NO
Phase Instantaneous Overcurrent (50PH1, 50PH2 and 50PH3)	YES / NO	NO
Phase Time Overcurrent (51PH1, 51PH2 and 51PH3)	YES / NO	NO
Ground Instantaneous Overcurrent (50G1, 50G2 and 50G3)	YES / NO	NO
Ground Time Overcurrent (51G1, 51G2 and 51G3)	YES / NO	NO
Negative Sequence Instantaneous Overcurrent (50NS1 and 50NS2)	YES / NO	NO
Negative Sequence Time Overcurrent (51NS1, 51NS2 and 50NS3)	YES / NO	NO
Sensitive Ground Instantaneous Overcurrent (50SG)	YES / NO	NO
Sensitive Ground Time Overcurrent (51SG)	YES / NO	NO
Open Phase	YES / NO	NO
Phase Overvoltage (59PH1, 59 PH2 and 59 PH3)	YES / NO	NO
Phase Undervoltage (27 PH1, 27 PH2 and 27 PH3)	YES / NO	NO
Ground Overvoltage (59N1 and 59N2 or 64_1 and 64_2)	YES / NO	NO
Overfrequency (81M1, 81M2, 81M3 and 81M4)	YES / NO	NO
Underfrequency (81m1, 81m2, 81m3 and 81m4)	YES / NO	NO
Frequency Rate of Change (81D1, 81D2, 81D3 and 81D4)	YES / NO	NO
Thermal Image (49)	YES / NO	NO
Programmable Trip (configurable in the programmable logic)	YES / NO	NO
External Trigger	YES / NO	YES
Power Supply Undervoltage	YES / NO	NO
Power Supply Overvoltage	YES / NO	NO

Analog Channel Mask (maximum 10 channels)	
1 - Phase A Current	7 - Phase A Voltage (depending on model)
2 - Phase B Current	8 - Phase B Voltage (depending on model)
3 - Phase C Current	9 - Phase C Voltage (depending on model)
4 - Ground Current	10 - Synchronism Voltage (depending on model)
5 - Sensitive Ground Current	
6 - Polarization Current	

Magnitude Selection
See 3.27

Note: each User Defined value configured in the Oscillography counts as 16 digital signals

Digital Channel Selection (maximum 80)
Selectable from all configurable Digital Inputs and Digital Signals

- **Oscillographic Recording: HMI Access**

0 - CONFIGURATION	0 - GENERAL	**0 - TRIP REQUIRED**
1 - OPERATIONS	1 - PROTECTION	**1 - CONTINUOUS MODE**
2 - ACTIVATE GROUP	...	**2 - PRETRIG. LENGTH**
3 - CHANGE SETTINGS	**7 - OSCILLOGRAPHY**	**3 - LENGTH**
4 - INFORMATION	...	**4 - TRIGGERS INTERVAL**
		5 - OSCILLO CHANN. MASK

3.30.13 Digital Inputs of the Oscillographic Recording

Table 3.30-1: Digital Inputs of the Oscillographic Recording

Name	Description	Function
TRIG_EXT_OSC	External Oscillography Trigger	Input intended for external triggering.
DEL_OSC	Deletion of Oscillographs	The activation of this input deletes all the oscillographs stored.
ENBL_OSC	Oscillographic Recording Enable Input	Activation of this input puts the element into service. The default value of this logic input signal is a “1.”

3.30.14 Auxiliary Outputs and Events of the Oscillographic Recording

Table 3.30-2: Auxiliary Outputs and Events of the Oscillographic Recording

Name	Description	Function
TRIG_EXT_OSC	External Oscillography Trigger	The same as for the digital input.
PU_OSC	Oscillography Picked Up	This output indicates that the oscillographic recording is on process.
DEL_OSC	Deletion of Oscillographs	The same as for the digital input.
ENBL_OSC	Oscillographic Recording Enable Input	Activation of this input puts the element into service. The default value of this logic input signal is a “1.”
OSC_ENBLD	Oscillographic Recording Enabled	Indication of enabled or disabled status of the element.

3.31 Fault Locator

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3.31.1 Introduction

DLX-B relays incorporate two fault locators, one based only on local measurements and the other using local and remote measurements. The first locator will only calculate the distance to the fault when, at the time of selecting prefault and fault magnitudes, remote measurements are not available, as a result, for example, of communications failure.

3.31.2 Locator with Local and Remote Measurements

The locator based on local and remote measurements carries out the calculation of the distance to the fault provided said measurements are available at the prefault and fault instants selected (see section 3.28, Fault Report). The locator algorithm uses only positive sequence network (both local and remote positive sequence currents and voltages) and so it is independent from likely errors included in zero sequence impedance and admittance values. In order to take into account the line capacitance, the algorithm uses a distributed parameter circuit, based on hyperbolic equations.

3.31.3 Locator with Local Measurements

The locator based only on local measurements will only operate when remote measurements at the prefault and fault instants selected in the Fault Report (see section 3.28) are not available. The algorithm removes the influence of the load, which may give rise to underreach and overreach with resistive faults when there is remote end infeed.

3.31.4 Fault Locator Settings

3.31.4.a Line Impedance

The settable electrical parameters of the line are: **Positive Sequence Impedance Magnitude**, **Positive Sequence Impedance Angle**, **Zero Sequence Impedance Magnitude**, **Zero Sequence Impedance Angle**, **Positive Sequence Admittance Magnitude**, **Positive Sequence Admittance Angle**, **Zero Sequence Admittance Magnitude** and **Zero Sequence Admittance Angle**, where all values are secondary ohms.

3.31.4.b Line Length

This setting corresponds to the length of the line that the locator is going to operate on. It is a dimensionless value.

3.31.4.c Length Units

The line **Length Units** setting allows selecting the unit of length, kilometers or miles, for the preceding setting.

3.31.4.d Locator Units

The **Locator Units** setting can be a unit of length or a percentage of the line length. When there is a fault, the locator will express the measurements according to this setting.

3.31.4.e Permanent Indication and Indication Duration

Once the distance to the fault is calculated, the location measurement variable will maintain the value calculated for some time. This time depends on the **Permanent indication** and **Indication Duration** settings.

If the **Permanent Indication** setting is **YES**, the value of the variable will not change until a new fault report is stored. Then it will change to the new value. In this operation mode, the location measurement will always be the value calculated for the last fault report stored.

If, on the contrary, the **Permanent Indication** setting is **NO**, the measurement variable will maintain the value for the time defined in the **Indication Duration** setting. If another fault report is stored meanwhile, the corresponding distance to the fault is not stored in the location measurement variable, although it is stored in its corresponding Fault Report record.

This operating mode is the same for the fault distance indication in the display as well as for the distance value which can be configured to be sent by communications through any of the available protocols.

3.31.4.f Minimum Zero Sequence Current Value

This setting affects only to the locator based on local data. You can set a zero sequence current ($3 \times I_0$) threshold value for single-phase faults. This way, if two and a half cycles after the pickup of the first element the $3 \times I_0$ magnitudes is less than this setting, the fault will be classified as an **Unknown Fault**. The setting is **Minimum Zero Sequence Current Value** and it refers to primary values.

3.31.4.g Indication Zone

The setting **Indication Zone** selects if the fault locator calculates distance to the fault for faults inside the protected line of for any fault detected by the relay. The availability of the information is limited to the display in the HMI, fault reports and communications.

With the option **Inside Line**, information is available for faults located inside the defined length for the protected line.

With the option **Inside and Outside**, information is available for any fault independent of the location being inside or outside of the defined length. It is important to consider the setting **Pickup Report**.

With the option **Inside Line** is possible to consider the pickup of the units. In any case all the faults are detected

The option Inside and Outside requires to set the **Pickup Report** to **YES** to be able to detect faults outside the protected line and calculate the distance to the fault (in these cases under normal operation the relay will not generate trips). Unless the directional units are set to reverse, the relay cans only pickup for faults upstream but never trip. Therefore the only way to detect such faults is via the pickup report. Same applies for faults located over 100% of the line length. If the relay is coordinated properly, and for normal operating conditions the relay will pickup but never trip. Again the only way to detect such faults is via the pickup report.

3.31.5 Phase Selector

The Fault Locator uses the **Phase Selector** (see 3.2) to determine the type of fault. Then the algorithm for each type of fault determines the distance to the fault.

The algorithm of the fault locator based on local and remote measurements does not need determining the type of fault as it uses exclusively the positive sequence network which is present in all types of faults.

3.31.6 Configuration of the Fault Locator

As indicated in section 3.31.1, the Fault Locator has two settings for sending the distance through remote communications (in the control profile):

Permanent Indication:	YES / NO
Indication Duration:	1 - 120 min

If the **Permanent Indication** setting is **NO**, the locator takes the **Indication Duration** setting into account for sending the distance through the communications profile. When a fault report occurs, the indication of the distance through the control profile lasts the time set. If a new fault occurs meanwhile, the distance sent by communications is still that of the first fault. When the set time transpires, an invalid value for the distance is sent. Now if a new fault occurs the distance to this last fault is sent. In contrast, the **Last Trip** indication in the display and the **Fault Report** always show the locator's distance for the last trip produced.

If the **Permanent Indication** setting is **YES**, communications always sends the distance of the last fault registered. If the relay has not registered a fault, it will be sending an invalid value.

The locator based exclusively on local measurements needs the determination of the type of fault. A number of conditions exist that make the fault to be classified as Unknown, in which case, said locator will not be able to calculate the distance to the fault:

- Single phase faults in which the value of $3xI_0$ is below **Minimum Value of Zero Sequence Current** setting:(0 - 500A in primary values). It involves faults with very high fault resistance, for which the locator error would be excessive.
- Faults lasting less than 2.5 cycles.
- Any fault produced during the 15 cycles following the closing of the breaker; this logic only takes into account the breaker status change, and has the purpose of reducing the locator sensitivity on inrush currents of the transformers energized when closing the breaker.

3.31.7 Location Information

- **From Display**

The indication of the distance to the fault can be set to be offered either in line length units (kilometers or miles) or in percentage of the line length. It is always accompanied by the type of fault (AN, BN, CN, AB, BC, CA, ABN, BCN, CAN and THREE-PHASE). The default screen will indicate this distance when there is a fault.

The messages that the fault locator can present in the display depend on the calculations that it performs. The possibilities are:

- Negative distances.
- Positive distances.
- When the locator lacks information for calculating the distance: the display shows UNKNOWN FAULT.
- While the distance is being calculated: the display shows the message, CALCULATING DISTANCE.

- **Fault Report**

The information about the distance to the fault that can appear in the report is the same as that shown in the display, that is, the elements are the same as those chosen to be presented in it. When the fault is unknown, however, the distance will be filled in with asterisks and the type of fault will be UNKNOWN FAULT.

- **Information via Remote Communications**

The distance to the fault value sent via communications by the protocol selected is fully configurable; that is, its **Full-Scale** value and the **Type of Elements** in which it is sent can be chosen.

The options for configuring it in the programmable logic so that it will be sent are: **Percentage Value**, the **Value in Kilometers** or the **Value in Miles**. The selection is totally independent of the magnitude used for presenting it on the display and in the fault reports.

With the ***ZivercomPlus***® it is possible to define the full-scale value to be used to transmit this magnitude in counts, the unit that all the protocols use. There are three definable parameters that determine the range of distance covered:

- **Offset value**: the minimum value of the magnitude for which 0 counts are sent.
- **Limit**: the length of the range of the magnitude on which it is interpolated to calculate the number of counts to send. If the offset value is 0, it coincides with the value of the magnitude for which the maximum defined counts are sent for each protocol (4095 counts for PROCOME and MODBUS and 32767 counts for DNP 3.0).
- **Nominal flag**: this flag allows determining whether the limit set is proportional to the rated value of the magnitude or not. The rated value of the new magnitudes defined by the user in the programmable logic can be configured, while the rest of the existing magnitudes are fixed.

The expression that allows defining this **Full-Scale** value is the following:

When the **Nominal Flag** is enabled:

$$CommunicationsMeasurement = \frac{Measurement - Offset}{Nominal} \times \frac{4095}{Limit} \text{ for PROCOME and MODBUS}$$

$$CommunicationsMeasurement = \frac{Measurement - Offset}{Nominal} \times \frac{32767}{Limit} \text{ for DNP 3.0}$$

When the **Nominal Flag** is NOT enabled,

$$CommunicationsMeasurement = (Measurement - Offset) \times \frac{4095}{Limit} \text{ for PROCOME and MODBUS}$$

$$CommunicationsMeasurement = (Measurement - Offset) \times \frac{32767}{Limit} \text{ for DNP 3.0}$$

Taking into account this system for sending values, if the distance is to be sent so that 0 counts are sent in 0% and the maximum number of counts allowed by the protocol are sent in 100%, the settings must be:

The **Percentage Value** of the distance is selected. The following settings are made:

Offset value = 0
Limit = 100
Nominal Flag = NO

To create a profile like that of figure 3.31.3, the following configuration is required:

The **Percentage Value** of the distance is selected. The following settings are made:

Offset value = -20
Limit = 120
Nominal Flag = NO

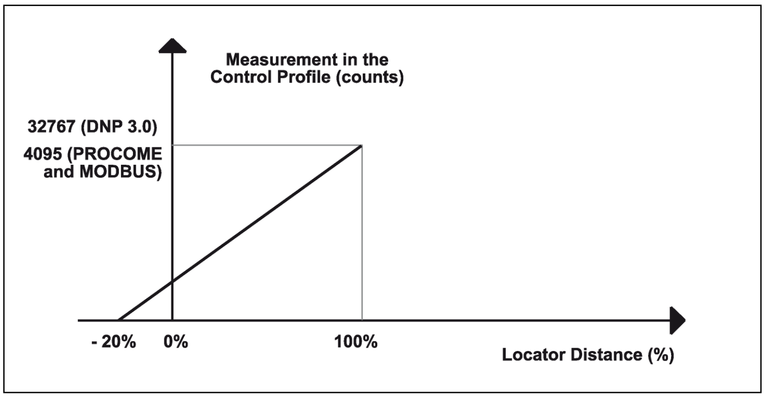

Figure 3.31.1 Scale of the Locator Measurements in the Control Profile.

Moreover, if between -20% and 0%, 0 counts should be sent, all that is needed is an algorithm in the programmable logic generating a user magnitude that is the **User Percentage Value**. This new magnitude is the one that will be sent via communications. It is generated as follows:

- An **Analog Selector** is configured. Its inputs are the **Percentage Value** and a **Zero**; its output is the **User Percentage Value**.
- A **Comparator** is configured to activate its output of **Greater than (>)** when the **Percentage Value** is greater than **0**, and subsequently *denies* this output.
- This *denied output* is used as a signal to control the **Analog Selector**.

Thus, the following is received via communications:

Distance: -20% → 0 counts
Distance: 100% → 32767 counts (DNP 3.0) or 4095 counts (PROCOME and MODBUS)

This way, if the distance that the locator calculates is greater than 100% or is less than or equal to 0%, the measurement sent in the control profile is **0** counts.

If the idea is to send the distance in kilometers or miles, sending the same number of counts as kilometers or miles shown on the display and the fault report will require the following configuration:

The value in **Kilometers** or **Miles** of the distance is selected. The following settings are made:

Offset value = 0
Limit = 4095 for PROCOME and MODBUS and 32767 for DNP 3.0
Nominal Flag = NO

As indicated previously, there are two locator settings in protection related to the transmission of the distance to control protocol: **Permanent Indication** and **Indication Duration**.

There is another input to the fault locator module, the **Restore the Distance to the Fault** input. Its function is to set the value of the distance to the fault and the type of fault that can be sent via communications to zero.

3.31.8 Fault Locator Settings

Line Impedance			
Setting	**Range**	**Step**	**By Default**
Positive Sequence Impedance Magnitude	0.001 - 10 ohm/L	0.001 ohm/L	0.5 ohm/L
Positive Sequence Impedance Angle	0 - 90º	0.1º	75º
Zero Sequence Impedance Magnitude	0.001 - 10 ohm/L	0.001 ohm/L	0.5 ohm/L
Zero Sequence Impedance Angle	0 - 90º	0.1º	75º
Positive Sequence Admittance Magnitude	0.1 - 1000 uS/L	0,001 uS/L	5 uS/L
Positive Sequence Admittance Angle	0 - 90º	0.1º	90º
Zero Sequence Admittance Magnitude	0.1 - 1000 uS/L	0.001 uS/L	5 uS/L
Zero Sequence Admittance Angle	0 - 90º	0.1º	90º
Line Length	0.01 – 1000 length units	0.01	50

Length and Units			
Setting	**Range**	**Step**	**By Default**
Line length unit	Km / Miles		Km
Locator unit	Length units / %		% of Length

Indication			
Setting	**Range**	**Step**	**By Default**
Permanent Indication	YES / NO		NO
Time Indication	1 - 120 min	1 min	5 min
Zero Sequence Min. Value ($3xI_0$)	0 - 500 A	0.01 A	0 A
Indication zones	0: Internal Faults 1: Internal and External		0: Internal Faults

- **Fault Locator: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - LINE DIFFERENTIAL
1 - OPERATIONS	**1 - PROTECTION**	1 - FUSE FAILURE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - DEAD LINE DETECTOR
3 - CHANGE SETTINGS	3 - LOGIC	3 - OPEN POLE LOGIC
4 - INFORMATION	...	4 - OVERCURRENT
		5 - VOLTAGE
		6 - FREQUENCY
		7 - OPEN PHASE DETECTOR
		8 - CT SUPERVISION
		9 - SYNCROCHECK
		10 - THERMAL IMAGE
		11 - COLD LOAD
		12 - PROTECTION SCHEME
		13 - BREAKER FAILURE
		14 - POLE DISCREPANCY
		15 - PHASE SELECTOR
		16 - PROTECTION LOGIC
		17 - FAULT LOCATOR

0 - LINE DIFFERENTIAL		
1 - FUSE FAILURE		
2 - DEAD LINE DETECTOR		**0 - LINE LENGTH**
...	**0 - LENGTH AND UNITS**	**1 - LENGTH UNITS**
17 - FAULT LOCATOR	1 - INDICATION	**2 - LOCATOR UNITS**

0 - LINE DIFFERENTIAL		
1 - FUSE FAILURE		**0 - PERMANENT INDICATION**
2 - DEAD LINE DETECTOR		**1 - TIME INDICATION**
...	0 - LENGTH AND UNITS	**2 - ZERO SEQ. MIN VALUE**
17 - FAULT LOCATOR	**1 - INDICATION**	**3 - INDICATION ZONE**

3.32 Inputs, Outputs & LED Targets

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3.32.1 Introduction

The **DLX** has a flexible, user-definable structure of **Inputs** / **Outputs** / **LEDs**. It is described in the following sections. Factory programming included default values. Settings can be changed using the software package ***ZivercomPlus***®.

3.32.2 Digital Inputs

The number of digital inputs available will depend on each particular model. All these inputs can be configured with any input signal to the pre-existing protection and control modules or defined by the user in the programmable logic.

The **Filtering** of the digital inputs can be configured with the following options:

- **Time between Samplings Filter 1** (**2-10 ms**): to establish the periodicity with which samples of the state of a digital input are taken.
- **Number of Samples with the same Value to Validate a Filter-1 Input** (**1-10**): the number of samples that must be detected consecutively to consider an input deactivated or activated can be set to logical "0" or "1" respectively.
- **Time between Samplings Filter 2** (**2-10 ms**): to establish the periodicity with which samples of the state of a digital input are taken.
- **Number of Samples with the same Value to Validate a Filter-2 Input** (**1-10**): The number of samples that must be detected consecutively to consider an input deactivated or activated can be set to logical "0" or "1" respectively.
- **Filter Assignation** (**Filter 1 / Filter 2**): Each configurable digital input can be assigned to "filter 1" or to "filter 2." The settings previously defined allow constructing filters 1 and 2 to create fast and slow detection inputs.
- **Number of Changes to Deactivate an Input and its Time Slot** (**2-60/1-30s**): an adjustable time slot is established to keep a digital input in which there is an external or internal malfunction to the relay from generating problems. This time slot monitors the number of times that this digital input changes condition. If this number of changes in state exceeds a set value, is disabled and the input keep on quite at its last status. Once an input is disabled, it will be enabled again when the enabling conditions are met or by an enabling command.
- **Number of Changes to Enable an Input and its Time Slot**: as for disabling, to enable an input again, there is also a time slot and a user-definable number of changes within that slot.

The IED's metering elements and logic functions use **Logic Input Signals** in their operation. They are enumerated in the tables nested in the description of each of them. Those corresponding to the IED's general services are listed in Table 3.32-1 and can be assigned to the **Physical Digital Inputs** or to logic output signals of opcodes configured in the programmable logic. More than one **Logic Input Signal** can be assigned to a **Single Status Contact Input**, but the same logic input signal cannot be assigned to more than one status contact input.

The tables mentioned above only list the inputs available with the default configuration. The list of inputs can be expanded with those that are configured in the programmable logic (any logic input signal created in the programmable logic can be used with the description that the user creates).

3.32.2.a Enable Input

Each protection element module of the relay has a special **Logic Input Signal** to put it “into service” or “out of service” from the HMI (buttons on the front), with a digital input by level and with the communications protocol configured in each port (control command).

This logic input signal is called **Enable Input…**. It combines with the **In Service** setting in this algorithm.

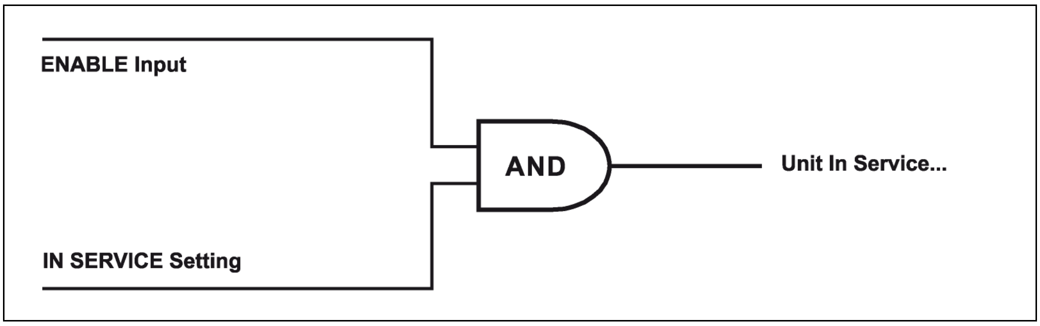

Figure 3.32.1 Element Enable Logic.

The default value of the logic input signal **Element Enable Input**... is a “1.” Therefore, when you do not configure the programmable logic at all, putting the protection elements into service depends only on the value of the **In Service** setting of each of them. The logic configuration to activate or switch off the enabling logic input signal will be as complicated or simple as you wish, from assigning it to a status contact input to building logical schemas with the various logic gates available (flip-flop’s, etc.).

Those protection functions that are put “out of service” by any of these methods will not generate or activate any of their associated logic signals, not even those that may be configured in the programmable logic and are directly related to these functions.

3.32.2.b Digital Inputs Settings

Digital Inputs			
Setting	**Range**	**Step**	**By Default**
Time between Samples (Filter 1)	2 - 10 ms	2	6 ms
Time between Samples (Filter 2)	2 - 10 ms	2	6 ms
Number of Samples to Validate Changes (Filter 1)	1 - 10 samples	1	2 samples
Number of Samples to Validate Changes (Filter 2)	1 - 10 samples	1	2 samples
Filter Assignation (Independent Setting for each DI)	0 = Filter 1 1 = Filter 2		0 = Filter 1
Number of Changes to Disable	2 - 60 changes	1	5 changes
Time to Disable	1 - 30 s	1	2 s
Number of Changes to Enable	2 - 60 changes	1	5 changes
Time to Enable	1 - 30 s	1	2 s
Automatic DI Disable (Independent for each IED Digital Input)	0 = NO 1 = YES	1	1

3.32.2.c Digital Inputs Table

Table 3.32-1: Digital Inputs		
Name	**Description**	**Function**
CEXT_TRIP	External Trip Control	It blocks all trips.
IN_BKR	Input of Breaker Position: Open (1) / Closed (0)	It monitors breaker status.
IN_RST_MAX	Maximeters Reset	Its activation sets the content of the current, voltage and power demand elements to zero.
IN_RST_DIS	Input of Distance to the Fault Reset	Its activation sets the value of the distance to the fault sent via communications to zero.
IN_PMTR_RST	Power Meters Reset	Its activation sets the content of the power meters to zero.
ENBL_PLL	Digital PLL Input Enable	Enables the operation of the automatic system to adapt to the frequency. By default, when not configured, it is a logic “1.”
LED_1	LED 1	They activate their corresponding LEDs.
LED_2	LED 2	
LED_3	LED 3	
LED_4	LED 4	
LED_5	LED 5	
LED_6	LED 6	
LED_7	LED 7	
LED_8	LED 8	

Table 3.32-1: Digital Inputs		
Name	**Description**	**Function**
CMD_DIS_DI1	Command to Disable Digital Input 1	Inputs to the module of digital inputs that activate and deactivate each of the digital inputs.
CMD_DIS_DI2	Command to Disable Digital Input 2	
CMD_DIS_DI3	Command to Disable Digital Input 3	
CMD_DIS_DI4	Command to Disable Digital Input 4	
CMD_DIS_DI5	Command to Disable Digital Input 5	
CMD_DIS_DI6	Command to Disable Digital Input 6	
CMD_DIS_DI7	Command to Disable Digital Input 7	
CMD_DIS_DI8	Command to Disable Digital Input 8	
CMD_DIS_DI9	Command to Disable Digital Input 9	
CMD_DIS_DI10	Command to Disable Digital Input 10	
CMD_DIS_DI11	Command to Disable Digital Input 11	
CMD_DIS_DI12	Command to Disable Digital Input 12	
CMD_DIS_DI13	Command to Disable Digital Input 13	
CMD_DIS_DI14	Command to Disable Digital Input 14	
CMD_DIS_DI15	Command to Disable Digital Input 15	
CMD_DIS_DI16	Command to Disable Digital Input 16	
CMD_DIS_DI17	Command to Disable Digital Input 17	
CMD_DIS_DI18	Command to Disable Digital Input 18 (*)	
REMOTE	Remote	Sets the relay in remote mode. Must be activated to enable DNP 3.0 commands.
LOCAL	Local Control	Means 'Local Commands' enabled, whose performance is defined in user's logic module.
CONTROL_PANEL	Operation Desk Control	Means 'Operation Desk Commands' enabled, whose performance is defined in user's logic module.

(*)The number of digital inputs and digital outputs available will depend on each particular model.

Table 3. 32-1: Digital Inputs		
Name	**Description**	**Function**
CMD_ENBL_DI1	Command to Enable Digital Input 1	Inputs to the module of digital inputs that activate and deactivate each of the digital inputs.
CMD_ENBL_DI2	Command to Enable Digital Input 2	
CMD_ENBL_DI3	Command to Enable Digital Input 3	
CMD_ENBL_DI4	Command to Enable Digital Input 4	
CMD_ENBL_DI5	Command to Enable Digital Input 5	
CMD_ENBL_DI6	Command to Enable Digital Input 6	
CMD_ENBL_DI7	Command to Enable Digital Input 7	
CMD_ENBL_DI8	Command to Enable Digital Input 8	
CMD_ENBL_DI9	Command to Enable Digital Input 9	
CMD_ENBL_DI10	Command to Enable Digital Input 10	
CMD_ENBL_DI11	Command to Enable Digital Input 11	
CMD_ENBL_DI12	Command to Enable Digital Input 12	
CMD_ENBL_DI13	Command to Enable Digital Input 13	
CMD_ENBL_DI14	Command to Enable Digital Input 14	
CMD_ENBL_DI15	Command to Enable Digital Input 15	
CMD_ENBL_DI16	Command to Enable Digital Input 16	
CMD_ENBL_DI17	Command to Enable Digital Input 17	
CMD_ENBL_DI18	Command to Enable Digital Input 18 (*)	
DO_1	Digital Output 1	They activate their corresponding outputs.
DO_2	Digital Output 2	
DO_3	Digital Output 3	
DO_4	Digital Output 4	
DO_5	Digital output 5	
DO_6	Digital Output 6	
DO_7	Digital Output 7 (*)	

(*)The number of digital inputs and digital outputs available will depend on each particular model.

3.32.3 Auxiliary Outputs

The number of digital outputs available will depend on each particular model. They can all be configured with any input or output signal of the pre-existing protection and control modules or defined by the user in the programmable logic.

The IED's metering elements and logic functions generate a series of logic output signals. Each of these signals has either a “true” or “false” value and this status can be used as an input to either of the combinational logic gates shown in figure 3.32.2. The use of the combinational logic gates described in figure is optional. Its purpose is to facilitate the simplest configurations. To develop more complex algorithms and be able to assign the resulting outputs to auxiliary contact outputs, the necessary opcodes must be programmed in the programmable logic.

The outputs from the blocks described in figure 3.32.2 can be connected to one of the programmable auxiliary contact outputs in the IED. There is an additional, non-programmable auxiliary output contact corresponding to relay **In Service**.

Two blocks of eight inputs are available. One of the blocks performs an **OR** operation with the selected signals (any signal activates the logic gate output). The other block performs an **AND** operation with the selected signals (all signals need to be active to activate the logic gate output). The result of these two blocks is then operated through either an **AND** or an **OR** gate. The pulse option can be added to the result of this operation. It works as follows:

- **Without Pulses**: by adjusting the pulse timer to 0, the output signal remains active as long as the signal that activated it lasts.
- **With Pulses**: once the output signal is activated, it remains the set time whether or not the signal that generated it is deactivated before or remains active.

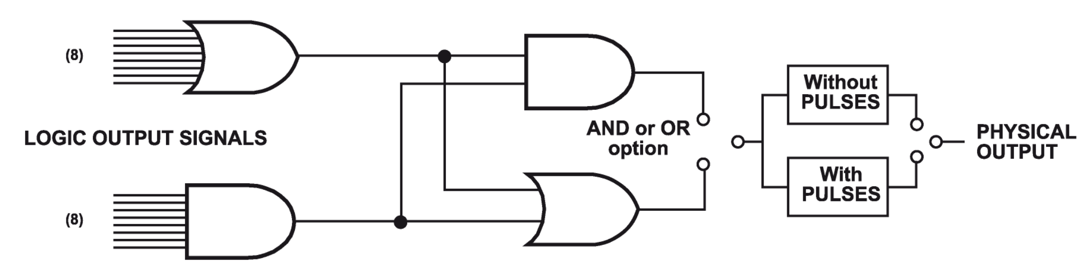

Figure 3.32.2 Auxiliary Contact Output Logic Cell Block Diagram.

All the logic output signals listed in the tables nested in the description of each of the elements are user-definable. Moreover, the signals indicated in Table 3.32-2, all corresponding to the IED's general services, can also be assigned.

The tables mentioned only list the logical outputs available with the default configuration. The list of signals can be expanded with those configured in the programmable logic (any logic signal created in the programmable logic can be used with the description that the user creates).

3.32.3.a Auxiliary Outputs Table

Table 3.32-2: Auxiliary Outputs		
Name	**Description**	**Function**
ACCESS_HMI	HMI Access	Indication that the HMI has been accessed.
SYNC_CLK	Clock Synchronization	Indication of having received a date / time change.
UN_PU	Any Element Picked Up	
RST_IND_TRIP	Reset Command of Trip Indication	When activated, it deletes the information about the last trip the relay has stored, thus also cleaning the display.
ACT_PROT	Trip By Protection	Signal indicating that the open / close command issued by the IED comes from the trip / close of some protection element.
B_OPEN	Open Button	They indicate that the corresponding button has been pressed.
B_CLS	Close Button	
B_BLOCK	Blocking / Unblocking Button	
IN_1	Digital Input 1	They indicate that the corresponding input has been activated.
IN_2	Digital Input 2	
IN_3	Digital Input 3	
IN_4	Digital Input 4	
IN_5	Digital Input 5	
IN_6	Digital Input 6	
IN_7	Digital Input 7	
IN_8	Digital Input 8	
IN_9	Digital Input 9	
IN_10	Digital Input 10	
IN_11	Digital Input 11	
IN_12	Digital Input 12	
IN_13	Digital Input 13	

Table 3.32-2: Auxiliary Outputs		
Name	**Description**	**Function**
IN_14	Digital Input 14	They indicate that the corresponding input has been activated.
IN_15	Digital Input 15	
IN_16	Digital Input 16	
IN_17	Digital Input 17	
IN_18	Digital Input 18 (*)	
VAL_DI_1	Validity of Digital Input 1	They indicate whether the input has been enabled or disabled.
VAL_DI_2	Validity of Digital Input 2	
VAL_DI_3	Validity of Digital Input 3	
VAL_DI_4	Validity of Digital Input 4	
VAL_DI_5	Validity of Digital Input 5	
VAL_DI_6	Validity of Digital Input 6	
VAL_DI_7	Validity of Digital Input 7	
VAL_DI_8	Validity of Digital Input 8	
VAL_DI_9	Validity of Digital Input 9	
VAL_DI_10	Validity of Digital Input 10	
VAL_DI_11	Validity of Digital Input 11	
VAL_DI_12	Validity of Digital Input 12	
VAL_DI_13	Validity of Digital Input 13	
VAL_DI_14	Validity of Digital Input 14	
VAL_DI_15	Validity of Digital Input 15	
VAL_DI_16	Validity of Digital Input 16	
VAL_DI_17	Validity of Digital Input 17	
VAL_DI_18	Validity of Digital Input 18 (*)	
CMD_DIS_DI1	Command to Disable Digital Input 1	The same as for the digital inputs.
CMD_DIS_DI2	Command to Disable Digital Input 2	
CMD_DIS_DI3	Command to Disable Digital Input 3	
CMD_DIS_DI4	Command to Disable Digital Input 4	
CMD_DIS_DI5	Command to Disable Digital Input 5	
CMD_DIS_DI6	Command to Disable Digital Input 6	
CMD_DIS_DI7	Command to Disable Digital Input 7	
CMD_DIS_DI8	Command to Disable Digital Input 8	

(*)The number of digital inputs and digital outputs available will depend on each particular model.

Table 3.32-2: Auxiliary Outputs		
Name	**Description**	**Function**
CMD_DIS_DI9	Command to Disable Digital Input 9	The same as for the digital inputs.
CMD_DIS_DI10	Command to Disable Digital Input 10	
CMD_DIS_DI11	Command to Disable Digital Input 11	
CMD_DIS_DI12	Command to Disable Digital Input 12	
CMD_DIS_DI13	Command to Disable Digital Input 13	
CMD_DIS_DI14	Command to Disable Digital Input 14	
CMD_DIS_DI15	Command to Disable Digital Input 15	
CMD_DIS_DI16	Command to Disable Digital Input 16	
CMD_DIS_DI17	Command to Disable Digital Input 17	
CMD_DIS_DI18	Command to Disable Digital Input 18 (*)	
CMD_ENBL_DI1	Command to Disable Digital Input 1	The same as for the digital inputs.
CMD_ENBL_DI2	Command to Disable Digital Input 2	
CMD_ENBL_DI3	Command to Disable Digital Input 3	
CMD_ENBL_DI4	Command to Disable Digital Input 4	
CMD_ENBL_DI5	Command to Disable Digital Input 5	
CMD_ENBL_DI6	Command to Disable Digital Input 6	
CMD_ENBL_DI7	Command to Disable Digital Input 7	
CMD_ENBL_DI8	Command to Disable Digital Input 8	
CMD_ENBL_DI9	Command to Disable Digital Input 9	
CMD_ENBL_DI10	Command to Disable Digital Input 10	
CMD_ENBL_DI11	Command to Disable Digital Input 11	
CMD_ENBL_DI12	Command to Disable Digital Input 12	
CMD_ENBL_DI13	Command to Disable Digital Input 13	
CMD_ENBL_DI14	Command to Disable Digital Input 14	
CMD_ENBL_DI15	Command to Disable Digital Input 15	
CMD_ENBL_DI16	Command to Disable Digital Input 16	
CMD_ENBL_DI17	Command to Disable Digital Input 17	
CMD_ENBL_DI18	Command to Disable Digital Input 18 (*)	
DO_1	Digital Output 1	The same as for the digital inputs.
DO_2	Digital Output 2	
DO_3	Digital Output 3	
DO_4	Digital Output 4	
DO_5	Digital Output 5	
DO_6	Digital Output 6	
DO_7	Digital Output 7 (*)	

(*) The number of digital inputs and digital outputs available will depend on each particular model.

Table 3.32-2: Auxiliary Outputs

Name	Description	Function
LED_1	LED 1	The same as for the digital inputs.
LED_2	LED 2	
LED_3	LED 3	
LED_4	LED 4	
LED_5	LED 5	
LED_6	LED 6	
LED_7	LED 7	
LED_8	LED 8	
IN_RST_LED	Leds Reset Input	Resets the LEDs that are active because they are memorized.
IN_PMTR_RST	Power Meters Reset Input	The same as for the digital input.
IN_RST_MAX	Maximeters Reset	Its activation sets the content of the current, voltage and power demand elements to zero.
IN_RST_DIS	Input of Distance to The Fault Reset	Its activation sets the value of the distance to the fault sent via communications to zero.
ENBL_PLL	Digital PLL Input Enable	The same as for the digital input.
RST_MAN	Manual Reinitialization of The Relay	It is marked whenever the IED is reset manually.
PU_CLPU	Cold Load Pickup of Relay	It is marked whenever the IED is energized.
PU_WLPU	Warm Pickup of Relay	It is activated after any reset (configuration loading, manual reset,…), while remaining de device powered-up.
INIT_CH_SET	Change of Settings Initialization	It is indicated when some setting is modified.
FAIL_COM_L	Port 0 Communication Failure	They activate when no communication port activity is detected during the set time.
FAIL_COM_R1	Port 1 Communication Failure	
FAIL_COM_R2	Port 2 Communication Failure	
FAIL_COM_R3	Port 3 Communication Failure	
REMOTE	Remote	Sets the relay in remote mode. Must be activated to enable DNP 3.0 commands.
LOCAL	Local Control	Means 'Local Commands' enabled, whose performance is defined in user's logic module.

Table 3.32-2: Auxiliary Outputs		
Name	**Description**	**Function**
CONTROL_PANEL	Operation Desk Control	Means 'Operation Desk Commands' enabled, whose performance is defined in user's logic module.
ERR_CRIT	Critical System Error	They note that some technical problem has cropped up in the IED.
ERR_NONCRIT	Non-Critical System Error	
EVENT_SYS	System Event	Indicates the reset of SW in the IED.

Configuration for outputs can be loaded at the factory. Users can easily program different output configurations using the ***ZivercomPlus***® software via the local communication ports that have the PROCOME protocol configured (the local port is always assigned this protocol).

3.32.3.b Trip and Close Outputs

DLX-A and **DLX-B** relays include from two to four physical operating outputs, respectively. In **DLX-A** relays said outputs are configured, in a fixed manner, with digital inputs "**Open command**" and "**Close command**" (see section 3.21, Control Logic). In **DLX-B** relays the operating outputs are configured, in a fixed manner, with "**Pole A Open Command**", "**Pole B Open Command**", "**Pole C Open Command**" and "**Close Command**" (see section 3.21, Control Logic).

As described in section 3.21, the open signals will be activated both by protection element trips and manual open commands. Similarly, close signals will be activated both by reclose commands and manual close commands.

3.32.4 LED Targets

The **DLX** IED has optical indicators (LEDs) on the front panel. One of them indicates whether the IED is **Ready**.

Each of the user-definable optical indicators is associated to a combinatorial function. These are diagramed in figure 3.32.3. They way they function and are configured is similar to the auxiliary contact outputs. One of the two blocks has eight inputs that perform an OR operation (any signal activates the output). The other block has one input. The two blocks together can perform an OR or an AND operation without the subsequent possibility of using pulses.

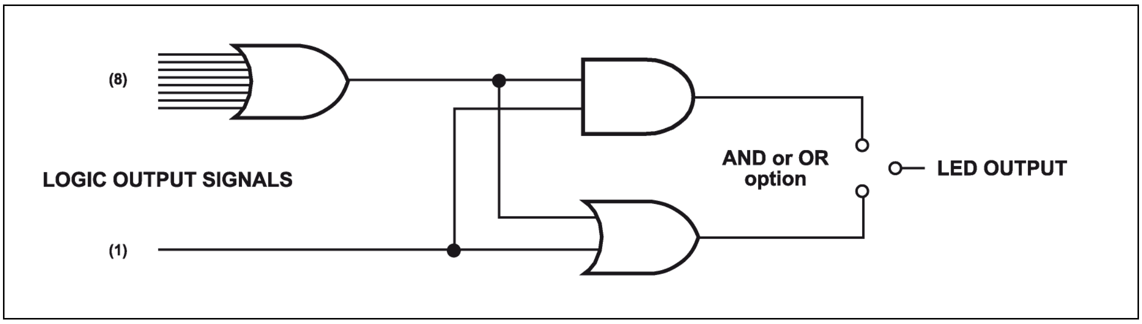

Figure 3.32.3 Target Output Logic Cell Block Diagram.

Each LED can be latched or unlatched. If an LED is latched, it will remain illuminated until reset. It is possible to program one of the programmable buttons, communications command, or digital input with the **Reset LEDs** digital input. Since it is defined as a command it will be available in the operations display menu. The latching function resides in the volatile memory section of the microprocessor. A power supply loss will cause any latched LED to reset.

The LEDs can be associated to any of the available logic output signals indicated in table 3.32-2. Logic equations can be created and modified with the ***ZivercomPlus***® program via the local communication ports that have the PROCOME protocol configured (the local port is always assigned this protocol).

To develop more complex algorithms and be able to assign the resulting outputs to the LEDs, the necessary opcodes must be programmed in the programmable logic. This, for example, allows configuring latched LEDs that do not lose memory after an auxiliary power supply voltage failure. This requires the use of latched bistable circuits.

3.32.5 Digital Inputs, Auxiliary Outputs and LED's Test

Apply rated voltage, appropriate for the model. At this time, the **In Service** LED should be lit.

- **Digital Inputs**

For the inputs test, the rated voltage is applied between the terminals corresponding to the inputs (marked in the external connections diagram), always taking the polarity of the contacts into account.

From the inputs screen of the **Information** menu, it is verified that the inputs are activated ("1"). The voltage is removed and the contact inputs must reset ("0").

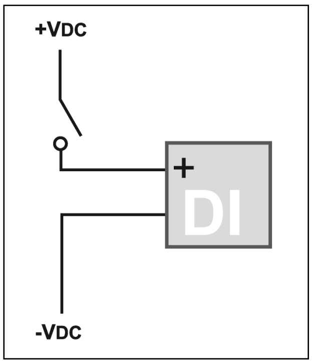

Figure 3.32.4 Digital Inputs Test.

- **Auxiliary Outputs**

To test the auxiliary contact outputs, their operation is provoked according to how they are configured. If they are not configured, they can be configured as activation of the status contact inputs. Part of the inputs test consists in verifying the operation of auxiliary output contacts.

- **LED Targets**

To check the LED targets, the **F2** key must be pressed from the stand-by screen until the Resetting LEDs screen appears. It is held down until all the LEDs light up. When the push-button is released, they must all go off.

3.33 Programmable Logic

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3.33.1 Description

One of the functions of **DLX** models is a fully configurable one called Programmable Logic. The user can freely interconnect this logic digitally and analogically by using the ***ZivercomPlus***® program.

All the signals generated by the equipment will be available to the events, oscillograph records, digital inputs and outputs, HMI and communications according to how their programmable logic has been configured.

From the signals or readings generated by any of the functions of the relay (Protection units, Digital inputs, Communications, Command functions and Analog inputs), the user can define a logical operation using primitive logic functions (AND, OR, XOR, NOT, etc.), bistable circuits (latched or not), timers, comparators, constants, values, etc.

The programming function allows definition of the trip logic, control logic, interlocks, functional modules, local and remote states and control hierarchy required for complete protection and operation of a bay.

It is also possible to choose priorities in the execution of the programmed algorithm so that some parts of this algorithm are executed in less and less time than other lower priority parts of the same logic.

The processing of the input signals produces logical outputs that can be assigned to existing connections between the IED and the exterior: auxiliary output contacts, display, LEDs, communications, HMI, etc.

Maximum size for the programmable logic will be 64kb; i.e. around 1000 primitive logic gates.

3.33.2 Functional Characteristics

The IEDs can execute local programmable control functions associated with the bay as well as the logic associated with internal and external interlockings, treatment and generation of alarms and processing of signals. They are all programmable.

The execution of interlockings towards the external circuits implies being able to execute continuously active outputs depending on the combination of the state of various input signals through logic gates. These interlocking outputs are used for interrupting / continuing an exterior command circuit. These interlockings are the consequence of the logic capacity pointed out in the following sections.

The execution of internal interlockings implies being able to obtain logic outputs of permission / blocking of commands towards the external circuits according to the combination of the state of various input signals through logic gates. These processed logic signals affect the permissions / lockouts of commands generated both from the unit's local control module and from the Central Unit originating in the control display, central programmable control functions and/or remote.

Logical alarms can be generated with data from the combination of the state of various input signals through logic gates as well as from "timers" of presence / absence of a given signal, either physical or logic.

The processing of analog signals offers the possibility of comparing analog inputs with set points and of generating digital ON/OFF signals as a result of this comparison as well as the possibility of adding and multiplying analog signals. Analog values can be used in primary or secondary values.

Logic configurations can also generate user defined values such as counters. These values are the result of the user defined logic algorithms. User defined values can be displayed on the HMI, sent via communications and retrieved using ***ZivercomPlus***®.

Likewise, it is also possible to define new user settings in the IED associated with the logic. These settings can be consulted afterwards from the HMI or communications.

In addition, the logic configurations can disable protection elements of the IED. The disabling of an element allows it to be replaced by another that operates under user-defined algorithms.

Basically, the system takes input signals from various sources, both external to the IED (communications or HMI) and internal; processes these signals according to the configuration that has been loaded and the pre-established settings and activates certain output signals that will be used for sending information messages or measurements to the central unit as well as commands to relays, LEDs and protection or logic units.

The **Programmable Logic** and its **Configuration** comprise the engine of this whole system. The logic has a set of *blocks* that encompass a series of logic operations. Each of these blocks determines an *outcome* (state of one or more signals) depending on the state of the inputs of that *block*. The **Configuration** determines the use of one or another block.

The operation chosen to obtain a given output determines the input signals to the *blocks*. The **Input Connection** process is the software process that connects the inputs of the *blocks* with the appropriate inputs to the control subsystem according to the **Configuration**.

Likewise, the output signals from the *blocks* are associated with the appropriate outputs. This is done in the **Output Connecting** process according to the **Configuration**.

If the required input signals are signals that arrive through communications, they arrive encoded according to the PROCOME, MODBUS or DNP 3.0 communications protocol, which forces associating each necessary signal with its corresponding protocol. This process is performed in **Input Tagging** and the associations are made in one form or another according to the configuration. The same happens with the signals sent through communications; the software process is carried out in **Output Tagging** and is also determined by the **Configuration**.

New logic-generated values can be redirected to the IED's different communication protocols as well as to the HMI.

The **Programmable Logic** can be used to generate events with any available digital signal that the IED can capture with the PROCOME communications protocol and the program. It doesn't matter if this signal is a digital input or a signal received via communications from the central unit or, on the contrary, is the outcome of internal operations included in the programmed algorithm itself. Moreover, there is the option of recording the event by the rising edge of the chosen signal, by the falling edge or by both.

Once the event is generated, it can be captured the same as the rest of the events generated by the IED (as, for example, trip events) with the ***ZivercomPlus***® communications program.

There is an exclusive option to simplify the task of configuring the Digital Inputs, Digital Outputs and LEDs. This voids the need to work with complex algorithms that would make the task unnecessarily difficult.

3.33.3 Primitive Functions (Opcodes)

The following logic operations can be used in the algorithm.

AND	Pulse	Adder	Digital/Analog Converter
OR	Timer A	Subtracter	BCD/Analog Converter
XOR	Timer B	Multiplier	Binary/Analog Converter
NOT	DFF	Divisor	Analog/BCD Converter
Cable	RSFF	Comparator	Analog/Binary Converter
Multifiber Cable	Analog Cable	Level Comparator	Pulse train
Multiplexer	Counter		Rising edge

3.33.3.a Logic Operations

- **AND**

Performs an AND operation between digital signals.

Operands:

From 2 to 16 digital input signals

Results:

Digital output signal, the outcome of the operation

- **OR**

Performs an OR operation between digital signals.

Operands:

From 2 to 16 digital input signals

Results:

Digital output signal, the outcome of the operation

- **XOR**

Performs an XOR operation between two digital signals.

Operands:

Two digital input signals.

Results:

Digital output signal, the outcome of the operation.

- **NOT**

Moves to a digital signal the outcome of negating another.

Operands:

Digital input signal.

Results:

Digital input signal.

- **Cable**

Moves to a digital signal the value of another.

Operands:

Digital input signal.

Results:

Digital input signal.

- **Multifiber Cable**

Moves to a digital signal the value of another.

Operands:

Digital input signal.

Results:

From 1 to 16 digital output signals.

- **Multiplexer**

Based on a selector, it establishes the value of an output signal with the value of one of the two inputs.

Operands:

Digital input selector signal.
2 digital input signals.

Results:

Digital output signal.

- **Analog Selector**

Based on a selector, it establishes the value of an analog output magnitude with the value of one of the two analog input magnitudes.

Operands:

Digital input selector signal.
2 analog input magnitudes.

Results:

Analog output magnitude.

- **Pulse**

When the input signal goes from 0 to 1, the output signal is activated during the time specified as parameter.

Operands:

Digital input signal.
Setting or pulse time constant in seconds.

Results:

Digital output signal.

Limits:

The maximum time must be set between 0.0 and 2147483.648 seconds (24 days).

- **Timer A**

When the time set since the input signal went from 0 to 1 is up, the output goes to one until the input resets.

Operands:

Digital input signal.
Setting or delay time constant in seconds.

Results:

Digital output signal.

Limits:

The maximum time must be set between 0.0 and 2147483.648 seconds (24 days).

- **Timer B**

The output is activated as long as the input is active or has been deactivated after a time no greater than the time set.

Operands:

Digital input signal.
Setting or delay time constant in seconds.

Results:

Digital output signal.

Limits:

The maximum time must be set between 0.0 and 2147483.648 seconds (24 days).

- **DFF**

Type D bistable. Whenever a rising edge occurs in the clock signal, the bistable takes the value of the input.

Operands:

Digital clock signal.
Digital input signal.

Results:

Digital output signal

- **RSFF**

Type RS bistable. As long as the S signal is active, the bistable takes the value of the input. When the R input is activated, the bistable takes value 0.

Operands:

Digital signal R.
Digital signal S.

Results:

Digital output signal.

- **Analog Cable**

Moves to an analog magnitude the value of another.

Operands:

Input magnitude.

Results:

Output magnitude.

- **Counter**

It manages a counter that increases with each rising edge of the clock signal. When the reset input is activated, the counter resets to 0.

Operands:

Digital reset signal.
Digital clock signal.

Results:

Magnitude of counter value.

Limits:

The counter has a saturation value of 65535. Subsequent increments do not modify the output value of the counter.

- **Adder**

It establishes the value of the output magnitude with the result of the sum of the input values.

Operands:

2 input values, settings or constants.

Results:

Output magnitude.

- **Subtracter**

It establishes the value of the output magnitude with the result of the subtraction of the input values.

Operands:

2 input values, settings or constants.

Results:

Output magnitude.

- **Multiplier**

It establishes the value of the output magnitude with the result of the product of the input values.

Operands:

2 input values, settings or constants.

Results:

Output magnitude.

- **Divisor**

It establishes the value of the output magnitude with the result of the division of the input values.

Operands:

2 input values, settings or constants.

Results:

Output magnitude.

- **Comparator**

Compares two input values and establishes the value of the digital output signal according to the outcome of the comparison.

Operands:

2 input values, settings or constants.
Type of comparison as a constant value inserted in the opcode:
Greater than.
Less than.
Equal to.
Not equal to.
Greater than or equal to.
Less than or equal to.

Results:

Digital output signal.

- **Level Comparator**

It compares the input magnitude with respect to a minimum and maximum reference value and establishes the output according to it. Thus:

The output is 1 if the input is greater than the maximum reference value.
The output is 0 if the input is less than the minimum reference value.
Otherwise, the output keeps the same value.

Operands:

Input magnitude (magnitude, setting or constant).
Minimum reference value (magnitude, setting or constant).
Maximum reference value (magnitude, setting or constant).

Results:

Digital output signal.

- **Digital / Analog Converter**

It converts a digital signal to an analog magnitude with value 0 or 1.

Operands:

Digital input signal.

Results:

Analog output magnitude.

- **BCD / Analog Converter**

With 16 digital inputs, it generates an analog magnitude using BCD code.

Operands:

16 digital input signals.

Results:

Analog output magnitude.

- **Binary / Analog Converter**

With 16 digital inputs, it generates an analog magnitude using binary code.

Operands:

16 digital input signals.

Results:

Analog output magnitude.

- **Analog / BCD Converter**

It converts an analog magnitude into 16 digital signals by converting to BCD code.

Operands:

Analog input magnitude.

Results:

16 digital output signals.

- **Analog / Binary Converter**

It converts an analog magnitude into 16 digital signals by converting to binary code.

Operands:

Analog input magnitude.

Results:

16 digital output signals.

- **Pulse Train**

Logic block produced by a pulse train while the digital input signal is active.

Operands:

Digital signal enabling pulse train.
Magnitude, setting or time constant of active pulse in seconds.
Magnitude, setting or time constant of inactive pulse in seconds.

Results:

Digital output signal.

- **Rising Edge**

The output is activated when a change from 0 to 1 is detected in the input.

Operands:

Digital input signal.

Results:

Digital output signal.

3.33.3.b Logic Operations with Memory

Certain logical functions can be configured to preserve the internal state of the function after a shut down. Not all the logical functions have internal states that require this treatment:

Table 3.33-1: Logic Operations with Memory

Logical function	Can be memorized
AND	-
OR	-
XOR	-
NOT	-
Cable	-
Multifiber cable	-
Pulse	Y
Timer A	Y
Timer B	Y
DFF	Y
RSFF	Y
Analog cable	-
Counter	Y
Adder	-
Subtracter	-
Multiplier	-
Divisor	-
Comparator	-
Level comparator	Y
Digital to analog	-
RSFF with timed reset	Y
Pulse train	Y

Memorization mode is selected by means of a memory field inserted in the opcode when configuring with the ***ZivercomPlus***® program.

3.34 Communications

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3.34.1 Communications Ports

DLX relays include, on the one hand, ports for communications with other remote relay, in order to be able to carry out the differential function (see section 3.1). Said ports include a monomode fiber optic interface with ST connector. Port optic gain is 20dB. The distance reached without repeaters is about 24km with fiber 9/25μm and 1310nm wave length.

On the other hand, DLX relays are provided with different types of communications ports as a function of the selected model:

- **1** front **Local Port** type RS232C.
- Up to **3 Remote Ports** with following configurations:
  - Remote Port 1: optical fiber interface (glass ST or plastic 1mm), electrical interface RS232 / RS485.
  - Remote Port 2: optical fiber interface (glass ST or plastic 1mm), electrical interface RS232 / RS485.
  - Remote Port 3: optical fiber interface (glass ST or plastic 1mm), electrical interface RS232 / RS232 FULL MODEM.

Technical data for these communications links can be found in Chapter 2.1 (Technical Data). Information on model ports can be found in chapter 1.4 (Model selection).

In this section only the features of the ports used for protection and control management are described. Information on the ports used for the differential function can be found in Section 3.1.

3.34.2 Communication with *ZivercomPlus*®

Protection, loading or reading programmable logic configuration and reading out protection data (events, fault reports, oscillograms,...) can be configured through communications ports set for PROCOME protocol. The local port is always assigned this protocol, whereas for remote ports it depends on settings.

Communications are established through ***ZivercomPlus***® communications program, which allows dialog between the **DLX** family and other relays, whether locally (via a PC connected to front port) or remotely (via rear serial ports with PROCOME protocol), covering all needs regarding programming, settings, recording, reports, etc..

Local and remote communications ports are configured through HMI.

DLX model features three controllers, one for each communications port, so that communications can be established through all of them at the same time.

The ***ZivercomPlus***® communications program that involves the application of the model involved is protected against non-authorized users through access passwords. The ***ZivercomPlus***®, that runs in WINDOWS™ environment is easy to operate and uses buttons or keys to display the different submenus.

3.34.3 Synchronization by IRIG-B 123 and 003

DLX relays are provided with a BNC type input for IRIG-B 123 or 003 standard time synchronization signals. Said input is located at the relay rear panel. Synchronization accuracy is ±1ms for events tagging and ±25us for Differential unit synchronization.

In case the relay is receiving an IRIG-B synchronization signal, access from HMI to **Date and Time** settings is denied.

An output can be configured to show IRIG-B signal received status. This output remains active while the relay receives correctly said signal.

Relays are also prepared for indication of both the loss and recovery of IRIG-B signal by generating events associated to each of these circumstances.

3.34.3.a UTC / Local Time Configuration

Discerning whether the time received through BNC connector corresponds to **UTC Time** or a given **Time Zone (Local)** is possible through **IRIG-B Time Zone** setting.

In the first case, a correction must be introduced to adapt the UTC time to the time zone of the relay site. The **Local Time Zone** setting within the **Date and Time** settings group is used for this purpose, which allows putting UTC time forward or back as required.

In the second case, the relay receives the time signal already adapted to the local time zone and no correction is needed. In this case local **Local Time Zone** has no effect.

3.34.3.b IRIG-B Function Settings

IRIG-B Function Settings			
Setting	**Range**	**Step**	**By Default**
IRIG-B Time Zone	0 = Local Time 1 = UTC Time	1	0 = Local Time

3.34.3.c Auxiliary Outputs of the IRIG-B Function

Table 3.34-1: Auxiliary Outputs of the IRIG-B Function		
Name	**Description**	**Function**
SIGNAL_IRIGB	IRIGB Active	Signal indicates that IRIG-B signal is being received.

3.34.4 Communications Protocol

All **DLX** relays are provided with rear communications ports for remote access and one front port for local access. Depending on model, rear ports feature several communications protocols:

- **Local Port**: uses only PROCOME protocol.
- **Remote Ports 1, 2** and **3**: options PROCOME, DNP3.0 and MODBUS are available.

It is worth mentioning that communications through all ports can be maintained simultaneously.

PROCOME protocol complies with IEC-870-5 standards and is used for both protection and control information management. On the other hand, protocols DNP 3.0 and MODBUS are used for control information management.

For more details on protocols refer to the applicable protocol paragraph.

3.34.4.a Control Change Recording

Depending on signals configured into the programmable logic through the ***ZivercomPlus***® program, the different system events make changed-state signals to be written.

Different signal lists for PROCOME 3.0 and DNP 3.0 protocols can be configured through the programmable logic, saving changes into different and separate **DLX** relay files for each of the communications ports. This implies that although the tail of changes of one port is emptied after collecting said information, the same information is available at the other port for collection through the allocated protocol, whether it is the same as for the first port or not.

Also, from the signals configured in PROCOME, DNP 3.0 or both, signals to be displayed through the HMI can be selected. They are also saved into separate files, so that even if tails of control changes of communications ports are emptied, the information is still available through HMI. Between 100 and 115 records are saved depending on their simultaneity.

Information on the Control Change Record is displayed from the HMI or pressing F1 key through **Information** option, the changes list view or delete options being available. If the view option is selected, the last change generated is always displayed (the most recent). Information is presented as follows:

AA/MM/DD|HH:MM:SS
000 text1 □ or ■
001 text2 □ or ■

AA/MM/DD|HH:MM:SS
000 text3 □ or ■
001 text4 □ or ■

Namely, events are grouped by “date” and “time”. Then, in the following line, the milliseconds corresponding to each control change and the label defined through the ***ZivercomPlus***® (maximum of 13 characters) are shown. And at the end of the line, a filled or blank square indicates ACTIVATION-ON (■) or DEACTIVATION-OFF (□) respectively. Default signal text labels are defined in input and output tables; in case of new signals generated into the programmable logic, said text must be defined. In any case, in order to use the names required by each user, the creation of a logic record card allocating a personalized name to every signal to be displayed is recommended.

The date and time stamp will be generated every time a new event occurs in it.

The MODBUS allows to display the actual value of the configured digital signals but do not record their changes.

3.34.5 Communications Settings

As the below described settings are independent for each port, they are grouped as follows: **Local Port**, **Remote Port 1**, **Remote Port 2** and **Remote Port 3**. Finally specific settings for each protocol are described.

Whenever communication is established through one of these ports, the following codes are displayed on relay alphanumeric HMI:

- **Local port**: **[PL]** code.
- **Remote port 1**, **Remote port 2**, **and Remote port 3**: **[P1]**, **[P2]** and **[P3]** codes.

These codes, in case of PROCOME 3.0 protocol, remain displayed during **Communications Password TimeOut** setting indicated in paragraph 3.31.4.d after the last communication carried out; in case of MODBUS and DNP V3.00 protocols, the message remains displayed for one minute after the last communication.

There are three timer settings, one for each communications port (**Communication Failure Time Indication**), which, no matter the assigned protocol, allow configuring the period without communication activity before generating the alarms (digital signals and events) **Communication Failure Port 0**, **1**, **2** and **3**.

3.34.5.a Local Port

The setting options of the local communications port are:

- **Baud Rate**: a value from 300 bauds to 38400 bauds can be chosen, default value being 38400 bauds.
- **Stop Bits**: one of two stop bits can be selected.
- **Parity**: even, odd or no parity (None) can be selected. No parity is configured by default.
- **Character Reception Time** (0-60000 ms): maximum time between characters allowed during the receiving of a message. The current message will be considered cancelled if it exceeds the set time between the reception of two characters.
- **Communication Failure Indication Time** (0-600 s.): maximum time between messages without indication of communication channel blocking.

3.34.5.b Remote Ports 1 and 2

Remote ports 1 and 2 have fiber optic and electrical access RS232 / RS485. Available configuration settings for these ports are similar to the local port settings, and it is possible to select the communications protocol and a specific parameter for RS485 application. Thus, settings are:

- **Baud Rate, Stop Bits, Parity** and **Character Reception Time**.
- **Protocol**: Depending on model, PROCOME 3.0, DNP 3.0 and MODBUS protocols (this last option is only available for remote port 2) can be selected. The default protocol is PROCOME.
- **Advanced settings**:
  1. Operation Mode (RS232 / RS485): This setting allows selecting the operation mode of DB9 interface of remote port 2 or 3 as a RS232 port or RS485 port.
  2. Time
    Transmission Time Factor (0-100 characters): Per-character time factor which determines when the transmission ends by time-out.
    Transmission Time Constant (0-60000 ms): Fixed time in seconds that is added to the per-character time factor, and that determines when the transmission ends by time-out.
    Number of 485 Stop Bytes (0-4 bytes): It specifies the number of stop bytes between transmit and receive when the port is configured as RS485.
  3. Message modification
    Number of Zeros (0-255): Number of zeros to insert as preamble to each message.
  4. Collisions
    Type of Collision (NO / ECHO / DCE):
      NO: Collision detection disabled.
      ECHO: A collision is considered to have occurred when the characters received do not coincide with the characters transmitted.
    Number of Retries (0-3): Maximum number of retries in the transmission when collisions are detected.
    Minimum Time between Retries (0-60000 ms): Minimum time between retransmissions on collision detection.
    Maximum Time between Retries (0-60000 ms): Maximum time between retries on collision detection.

3.34.5.c Remote Port 3

Remote port 3 has fiber optic and electrical access RS232 / RS232 FULL MODEM. Access through RS232 FULL MODEM has all the MODEM lines in format DB9. The settings available for configuring this port are:

- **Baud Rate, Stop Bits, Parity** and **Character Reception Time**, the same as the local port.
- **Protocol**: depending on model, PROCOME 3.0, DNP 3.0, MODBUS Protocols and Virtual Inputs Outputs can be selected. The default protocol is PROCOME.
- **Advanced Settings**:
  1. Flow Control
    CTS Flow (NO / YES): It specifies whether the **Clear to Send** signal is monitored to control the data transmission flow. If the setting is YES and the CTS signal falls to “0”, the transmission is suspended until the CTS signal resets.
    DSR Flow (NO / YES): It specifies whether the **Data Set Ready** signal is monitored to control the data transmission flow. If the setting is YES and the DSR signal falls to “0”, the transmission is suspended until the DSR signal resets.
    DSR Sensitive (NO / YES): It specifies whether the communications port is sensitive to the state of the DSR signal. If the setting is YES, the communications driver ignores any byte received unless the DSR line is active.
    DTR Control (INACTIVE / ACTIVE / ENABLE SEND):
      Inactive: It sets the DTR control signal to permanently inactive.
      Active: It sets the DTR control signal to permanently active.
      Enable Send: The DTR signal remains active as long as the receiving of new characters is allowed.
    RTS Control (INACTIVE / ACTIVE / ENABLE SEND / SOL. SEND):
      Inactive: It sets the RTS control signal to permanently inactive.
      Active: It sets the RTS control signal to permanently active.
      Enable Send: The RTS signal remains active as long as the receiving of new characters is allowed.
      Solicit Send: The RTS signal remains active as long as there are characters pending transmission.
  2. Time
    Transmission Time Factor (0-100 characters): Per-character time factor, which determines when the transmission ends by time-out.
    TRANSMISSION TIME CONSTANT (0-60000 ms): Fixed time in seconds that is added to the per-character time factor, and that determines when the transmission ends by time-out.
  3. Message modification
    Number of Zeros (0-255): Number of zeros to insert as preamble to each message.
  4. Collisions
    Type of Collision (NO / ECHO / DCD):
      NO: Collision detection disabled.
      ECHO: A collision is considered to have occurred when the characters received do not coincide with the characters transmitted.
      DCD: A collision is considered to have occurred when the DCD line is activated.
    Number of Retries (0-3): Maximum number of retries in the transmission when collisions are detected.
    Minimum Time Between Retries (0-60000 ms): Minimum time between retransmissions on collision detection.
    Maximum Time Between Retries (0-60000 ms): Maximum time between retries on collision detection.

3.34.5.d Ethernet Remote Ports 1, 2 and 3

- **Protocol**: Depending on model, PROCOME 3.0, DNP 3.0 and MODBUS protocols can be selected. The default protocol is PROCOME.
- **Ethernet**
  1. Enabling the Ethernet Port (YES-NO): enables (YES) or disables (NO) the Ethernet Port.
  2. IP Address (ddd.ddd.ddd.ddd): Ethernet device ID number.
  3. Net mask (128.000.000.000 – 255.255.255.254): number that indicates to the device what part of the IP address is the network number, and what part of the IP address corresponds to the device.
  4. Port Number (0 - 62235): number used to indicate the delivery route of the data received, to the destination device.
  5. Max. Time between Messages TCP (0-65 sec.): number of seconds between Keepalive packages - if zero then Keepalive packages were not sent. These Packages inform the server if a client is still present on the Ethernet Network.
  6. RX Car Time (0-60000 milliseconds): maximum time between characters allowed while receiving a message through the Ethernet. The message is timed out if the set time is exceeded between the receipt of two characters.
  7. Communication fault indication time (0-600 sec.): maximum time between messages via the Ethernet port before an indication that communications have stopped.

3.34.5.e PROCOME 3.0 Protocol Settings

The configuration settings of the PROCOME 3.0 protocol are:

- **Relay Number** (0-254): it specifies the address of the **DLX** relay (acting as RTU or Remote Terminal Unit) in relation to the rest of equipment that communicate with the same master station (MTU or Master Terminal Unit).
- **Communications Password Enable** (YES-NO): this setting allows to enable the access password function to establish communication with the relay through the rear port: YES means enabling the permission and NO, disabling.
- **Communications Password TimeOut** (1-10 minutes): this setting allows establishing a period of time for activating a communication blocking with the relay (whenever communication is via the rear port): if the set time expires with no activity taking place in the communications program, the system blocks, and the communication must be reinitiated.
- **Communications Password**: the communications password allows establishing a specific password to access communications with the relay through the rear port. This password must have 8 characters, which will be entered using the numerical keys and the key corresponding to a dot.

3.34.5.f DNP 3.0 Protocol Settings

The DNP 3.0 protocol configuration settings include the definition of:

- **Relay Number** (0-65519): it specifies the address of the **DLX** relay (acting as RTU or Remote Terminal Unit) in relation to the rest of equipment that communicate with the same master station (MTU or Master Terminal Unit). The 0xFFF0 to 0xFFFF addresses are reserved for the Broadcast addresses.
- **T. Confirm TimeOut** (100-65535): it specifies the time lapse (in milliseconds) from the time the **DLX** sends a message requesting the master to confirm the Application layer (Level 7), until this confirmation is considered lost. The **DLX** requests confirmation of the Application Layer when it sends spontaneous (Unsolicited) messages or in response to requests for Class 1 or Class 2 Data. When this time expires, the message is retransmitted the number of times specified in the N. Retries parameter.
- **N. Retries** (0-65535): number of retries of the Application Layer (N7). The default value is 0 (zero), indicating that no retransmission will be attempted.
- **Master Number Unsolicited** (0-65535): it specifies the address of the master station (MTU or Master Terminal Unit) to which the **DLX** relay will send spontaneous (Unsolicited) messages. It is used in combination with Enable Unsolicited parameter. Addresses 0xFFF0 to 0xFFFF are reserved for Broadcast addresses.
- **Enable Unsolicited** (YESI/NO): enables (YES) or disables (NO) sending spontaneous messages (Unsolicited); it is used in combination with the MTU Number parameter. For the **DLX** relay to begin sending spontaneous messages the master must also enable them with the Function Code FC = 20.
- **Unsolicited Start Enable** (YES/NO): enables (YES) or disables (NO) sending spontaneous start messages (Unsolicited after Restart); it is used in combination with the MTU Number parameter. For the **DLX** relay to begin sending spontaneous start messages there is no need for the master to enable them.
- **Time Grouping Unsolicited** (100-65535): it specifies the time interval between the generation of a first event for an unsolicited message and the transmission of the message, with the purpose of grouping several events that may occur within this time interval in a single transmission message, in order not to saturate the communications line with multiple messages.
- **Sync. Interval** (0-120 minutes): it specifies the maximum time interval between two synchronizations. If no synchronization occurs within the interval, the need for synchronization is set in Internal Indication (IIN1-4 NEED TIME). This setting has no effect if the Sync. Interval is 0.
- **Unsolicited Start Activation** (YES/NO): enables (YES) or disables (NO) sending Forced Unsolicited messages (for compatibility with versions pre DNP3-1998). When Unsolicited Start is activated, the **DLX** relay begins to transmit the existing spontaneous messages without additional enabling by the level 2. For this setting to have effect Enable Unsolicited Start must be enabled.
- **DNP3 Revision** (STANDARD ZIV/2003): indicates the DNP3 certification revision to use. STANDARD ZIV or 2003 (DNP3-2003 Intelligent Electronic Device (IED) Certification Procedure Subset Level 2 Version 2.3 29-Sept-03).

Up to 64 measurements or analog magnitudes can be set for DNP3 transmission. Among them, up to 16 measurements can be set for transmission upon a change request.

To select the measurements to transmit upon a change request, enable the **DNP3 Measurement Change** control configuration option using ***Ziverlog***®.

The measurement change transmission is set through two parameters for each measurement: **Upper Limit** (in profile **I** relays) or **Maximum Value** (in profile **II** relays) setting values and the **Band** setting value set for that measurement. Up to 16 band values may be configured through ***ZivercomPlus***®, which will be associated to the measurements enabled for change transmission in the same sequence as they are ordered in ***Ziverlog***®. Namely: band value 000 will be assigned to the first measurement enabled for change transmission, 001 to the second, and so on up to the last measurement enabled, with the limit of 16. The band represents a percentage of the **Maximum Value**, so that when a measurement change exceeds that band, the measurement value is annotated to be sent as change. When the relay receives a measurement change request, it will send all changes annotated.

Analog changes will not be annotated for measurements with option **DNP3 Measurement Change** enabled but with the band set to 100%, or measurements with option **DNP3 Measurement Change** not enabled, they being deemed disabled for change transmission.

Additionally, these are other settings defined for the **DNP3 Profile II and Profile II Ethernet Protocols**:

- **Class for binary changes** (CLASS..., NONE). Assigns the class to the binary changes.
- **Class for analog changes** (CLASS..., NONE). Assigns the class to the analog changes.
- **Class for counter changes** (CLASS..., NONE). Assigns the class to the counter changes.
- **"Status" type binary inputs** (YES-NO). Binary inputs used are according to "status" type inputs (YES) or binary inputs used are not sent according to "status" type inputs (NO).
- **32 bits analog inputs** (YES-NO). Analog inputs used are 32 bits resolution (YES) or analog inputs used are 16 bits resolution (NO).
- **Change in DNP3 Counter** (1 to 32767). The setting value shows the minimum increase of counts needed to send a new DNP3 message stating a new change in the counter. 20 counters can be configured as maximum under the DNP3 Profile **II** and Profile **II** Ethernet Protocols.

3.34.5.g MODBUS Protocol Setting

The only configuration setting of the MODBUS protocol is the **Relay Number** (0-254), which the same as for the other protocols specifies the **DLX** relay address (acting as RTU or Remote Terminal Unit) with reference to the rest of relays communicating with the same master station (MTU or Master Terminal Unit).

3.34.6 Setting Ranges

Local Port Communications			
Setting	**Range**	**Step**	**By Default**
Baud Rate	300 - 38400 Baud		38400
Stop Bits	1 - 2		1
Parity	None / Even / Odd		None
RX Time Between Character	1 - 60000 ms	0.5 ms	40 ms
Communication Failure Indication Time	0 - 600 s	0.1 s	60 s

Remote Communications Ports 1 and 2			
Setting	**Range**	**Step**	**By Default**
Protocol Selection	PROCOME DNP 3.0 MODBUS		PROCOME
Baud Rate	300 - 38400 Baud		38400
Stop Bits	1 - 2		1
Parity	None / Even / Odd		None
RX Time Between Character	1 - 60000 ms	0.5 ms	40 ms
Communication Failure Indication Time	0 - 600 s	0.1 s	60 s
Advanced Settings			
Operation Mode	RS232 / RS485		RS232
Time			
Tx Time Factor	0 -100 characters	0.5	1
Tx Time Constant	0 - 60000 ms	1 ms	0 ms
Number of 485 Stop Bytes	0 - 4 bytes	1 byte	0
Message Modification			
Number of Zeros	0 - 255	1	0
Collisions			
Type of Collision	NO / ECHO		NO
Number of Retries	0 - 3	1	0
Minimum Retry Time	0 - 60000 ms	1 ms	0 ms
Maximum Retry Time	0 - 60000 ms	1 ms	0 ms

Remote Communications Port 3			
Setting	**Range**	**Step**	**By Default**
Protocol Selection	PROCOME DNP 3.0 MODBUS		PROCOME
Baud Rate	300 - 38400 Baud		38400
Stop Bits	1 - 2		1
Parity	None / Even / Odd		None
RX Time between Character	1 - 60000 ms	0.5 ms	40 ms
Communication Failure Indication Time	0 - 600 s	0.1 s	60 s
Advanced Settings			
Flow Control			
CTS Flow	0 (NO) - 1 (YES)		NO
DSR Flow	0 (NO) - 1 (YES)		NO
DSR Sensitive	0 (NO) - 1 (YES)		NO
DTR Control	Inactive / Active / Permit send		Inactive
RTS Control	Inactive / Active / Permit send		Inactive
Time			
Tx Time Factor	0 -100 characters	0.5	1
Tx Time Constant	0 - 60000 ms	1 ms	0 ms
Message Modification			
Number of Zeros	0 - 255	1	0
Collisions			
Type of Collision	NO / DCD - ECHO		NO
Number of Retries	0 - 3	1	0
Minimum Retry Time	0 - 60000 ms	1 ms	0 ms
Maximum Retry Time	0 - 60000 ms	1 ms	0 ms

Remote Communications Ports 1, 2 and 3 Ethernet			
Setting	**Range**	**Step**	**By Default**
Protocol Selection	PROCOME DNP 3.0 MODBUS		PROCOME
Enabling the Ethernet Port	NO / YES		YES
IP Address	ddd. ddd. ddd. ddd		192.168.1.151(PR1) 192.168.1.61(PR2) 192.168.1.71(PR3)
Net Mask	128.000.000.000 - 255.255.255.254		255.255.255.0
Port Number	0 - 65535	1	20000
Max. Time between Messages TCP	0 - 65 s	1	30
RX Car. Time	0 - 60000 ms	0.5 ms	1 ms
Communication fault indication time	0 - 600 s	0.1 s	60 s

Communications Protocols			
Setting	**Range**	**Step**	**By Default**
PROCOME Protocol			
IED Address	0 - 254	1	0
Communications Password Enable	YES / NO		NO
Communications Password Timeout	1 - 10 min	1	10 min
Communications Password	8 characters		
DNP 3.0 Protocol			
IED Address	0 - 65519	1	1
T. Confirm Timeout	100 - 65535 ms	1	1000 ms
Max. Retries	0 - 65535	1	0
Enable Unsolicited	YES / NO		NO
Unsolicited Start Enable	YES / NO		
Unsolic. Master No.	0 - 65519	1	1
Unsolic. Grouping Time.	100 - 65535 ms	1	1000 ms
Sync Interval	0 - 120 min	1	0 min
Unsolicited Start Activation	YES / NO		
DNP 3.0 Revision	Standard ZIV / 2003		
DNP 3.0 Protocol: Measurements (16 Deadband Measurements Change)	0.01 - 100	0.01	100
DNP 3.0 Profile II Protocol: Measurements (16 Deadband Measurements Change)	0.0001 - 100	0.0001	100
Digital Changes Class (DNP 3.0 Profile II and Profile II Ethernet)	CLASS 1, CLASS 2, CLASS 3, NONE		CLASS 1
Analog Changes Class (DNP 3.0 Profile II and Profile II Ethernet)	CLASS 1, CLASS 2, CLASS 3, NONE		CLASS 2
Counters Changes Class (DNP 3.0 Profile II and Profile II Ethernet)	CLASS 1, CLASS 2, CLASS 3, NONE		CLASS 3
Validity Status for Digital Inputs (DNP 3.0 Profile II and Profile II Ethernet)	YES / NO		YES
32 Bits Measurements (DNP 3.0 Profile II and Profile II Ethernet)	YES / NO		YES
Counters (max. 20) (DNP 3.0 Profile II and Profile II Ethernet)	1 - 32767	1	1
MODBUS Protocol			
IED Address	0 - 247	1	1

- **Communications: HMI Access**

0 - CONFIGURATION	0 - NOMINAL VALUES	**0 - PORTS**
1 - OPERATIONS	1 - PASSWORDS	**1 - PROTOCOLS**
2 - ACTIVATE GROUP	**2 - COMMUNICATIONS**	
2 - CHANGE SETTINGS	3 - TIME AND DATE	
3 - INFORMATION	4 - DISPLAY CONTROLS	
	5 - DISP. LIGHT. T.OUT	
	6 - COMMAND BUTTONS	

Ports / CAN Ports

0 - PORTS	**0 - CAN**	**0 - BAUDRATE**
1 - PROTOCOLS	1 - LOCAL PORT	**1 - COMMS FAIL IND. TIME**
	2 - REMOTE PORT 1	
	3 - REMOTE PORT 2	
	4 - IRIG-B	

Ports / Local Port

0 - PORTS	0 - CAN	**0 - BAUDRATE**
1 - PROTOCOLS	**1 - LOCAL PORT**	**1 - STOP BITS**
	2 - REMOTE PORT 1	**2 - PARITY**
	3 - REMOTE PORT 2	**3 - RX TIME BTW. CHAR**
	4 - IRIG-B	**4 - COMMS FAIL IND. TIME**

Ports / Remote Ports 1 and 2

0 - PORTS	0 - CAN	**0 - PROTOCOL SELECT.**
1 - PROTOCOLS	1 - LOCAL PORT	**1 - BAUDRATE**
	2 - REMOTE PORT 1	**2 - STOP BITS**
	3 - REMOTE PORT 2	**3 - PARITY**
	4 - IRIG-B	**4 - RX TIME BTW. CHAR**
		5 - COMMS FAIL IND. TIME
		6 - ADVANCED SETTINGS

0 - PROTOCOL SELECT.	
1 - BAUDRATE	
2 - STOP BITS	
3 - PARITY	**0 - OPERATING MODE**
4 - RX TIME BTW. CHAR	**1 - TIME**
5 - COMMS FAIL IND. TIME	**2 - MESSAGE MODIF.**
6 - ADVANCED SETTINGS	**3 - COLLITIONS**

0 - OPERATING MODE	**0 - TX TIME FACTOR**
1 - TIME	**1 - TX TIMEOUT CONST.**
2 - MESSAGE MODIF.	**2 - STOP BYTES 485**
3 - COLLITIONS	

0 - OPERATING MODE	
1 - TIME	
2 - MESSAGE MODIF.	**0 - NUMBER OF ZEROS**
3 - COLLITIONS	

0 - OPERATING MODE	**0 - COLLISION TYPE**
1 - TIME	**1 - MAX RETRIES**
2 - MESSAGE MODIF.	**2 - MIN RETRY TIME**
3 - COLLITIONS	**3 - MAX RETRY TIME**

Ports / Ethernet Remote Ports 1, 2 and 3

0 - PORTS	0 - LOCAL PORT	
1 - PROTOCOLS	**1 - REMOTE PORT 1**	
	2 - REMOTE PORT 2	**0 - PROTOCOL SELECT**
	3 - REMOTE PORT 3	**1 - UART**
	4 - IRIG-B	**2 - ETHERNET**

0 - PROTOCOL SELECT	**0 - BAUDRATE**
1 - UART	**1 - STOP BITS**
2 - ETHERNET	**2 - PARITY**
	3 - RX TIME BTW. CHAR
	4 - COMMS FAIL IND.TIME
	5 - ADVANCED SETTINGS

0 - BAUDRATE	
1 - STOP BITS	
2 - PARITY	**0 - OPERATING MODE**
3-RX TIME BTW. CHAR	**1 - TIME**
4 - COMMS FAIL IND. TIME	**2 - MESSAGE MODIF.**
5 - ADVANCED SETTINGS	**3 - COLLITIONS**

0 - PROTOCOL SELECT.	**0 - ETHERNET PORT**
1 - UART	**1 - IP ADDRESS**
2 - ETHERNET	**2 - SUBNET MASK**
	3 - PORT NUMBER
	4 - KEEPALIVE TIME
	5 - RX TIME BTW. CHAR
	6 - COMMS FAIL IND.TIME

Ports / IRIG-B

0 - PORTS	0 - CAN	
1 - PROTOCOLS	1 - LOCAL PORT	
	2 - REMOTE PORT 1	
	3 - REMOTE PORT 2	
	4 - IRIG-B	**0 - IRIG-B TIME TYPE**

Protocols / Procome Protocol

0 - PORTS	**0 - PROCOME PROTOCOL**	**0 - UNIT NUMBER**
1 - PROTOCOLS	1 - DNP 3.0 PROTOCOL	**1 - COMMS PASSW. ENABLE**
	2 - MODBUS PROTOCOL	**2 - COMMS PASSW. TIMEOUT**
		3 - COMMS PASSW.

Protocols / DNP 3.0 Protocol

0 - PORTS	0 - PROCOME PROTOCOL	**0 - RELAY NUMBER**
1 - PROTOCOLS	**1 - DNP 3.0 PROTOCOL**	**1 - T. CONFIRM TIMEOUT**
	2 - MODBUS PROTOCOL	**2 - MAX RETRIES**
		3 - HAB. UNSOLICITED
		4 - UNSOL. PICKUP ACT.
		5 - UNSOLIC. MASTER NO.
		6 - UNSOL. GROUPING TIME
		7 - SYNCR. INTERVAL
		8 - BINARY CLASS
		9 - ANALOG CLASS
		10 - COUNTER CLASS
		11 - BINARY STATUS
		12 - 32 BIT ANALOG INP.
		13 - MEASURES
		14 - COUNTERS

Protocols / Modbus Protocol

0 - PORTS	0 - PROCOME PROTOCOL	
1 - PROTOCOLS	1 - DNP 3.0 PROTOCOL	
	2 - MODBUS PROTOCOL	**0 - UNIT NUMBER**

3.34.7 Communications Test

In order to proceed with the communications testing the relay must be supplied with the nominal voltage. Then the “In Service” LED must light up.

3.34.7.a PROCOME Protocol Test

The testing shall be performed through the three communications ports (one front and two rear [P1 and P2] ports), which must be set as follows:

Baud rate	38,400 bauds
Stop bits	1
Parity	1 (even)

All ports shall be assigned the PROCOME protocol in order to use the ***ZivercomPlus***® communications program in all of them.

Connect with the relay through the front port via a male DB9 cable. Synchronize the time through the ***ZivercomPlus***® program. Disconnect the relay and wait for two minutes. Then, supply power to the relay again and connect with the relay through both rear ports. Finally set the ***ZivercomPlus***® program to cyclic and check that the time updates properly with both P1 and P2 connected.

3.34.7.b DNP v3.0 Protocol Tests

The main objects to test are:

1	0	Binary Input – All variations
1	1	Binary Input

The relay is asked about the state in that instant of the IED's status contact input signals (digital inputs, digital outputs, logic signals) configured to be sent via DNP v3.0.

2	0	Binary Input Change – All variations
2	1	Binary Input Change without Time
2	2	Binary Input Change with Time
2	3	Binary Input Change with Relative Time

The relay is asked about the control changes generated by the status contact input signals configured to be sent via DNP v3.0. They can be all the changes, without time, with time or with relative time.

10	0	Binary Outputs – All variations

The relay is asked about the state of the writings of outputs configured in the relay.

12	1	Control Relay Output Block

The operations sent through communications are tested on the IED.

20	0	Binary Counter – All variations
20	1	32-bit Binary Counter
21	0	Frozen Counter – All variations
21	1	32-bit Frozen Counter
22	0	Counter Change Event – All variations

A request is made for the value of the counters included in the IED's logic. These counters can be 32-bits binary or frozen counters. A request is also made for the changes generated by the value of these counters.

30	0	Analog Input – All variations
30	2	16-Bit Analog Input

A request is made for the value of the IED's analog inputs at that precise moment.

32	0	Analog Change Event – All variations
32	4	16-Bit Analog Change Event with Time

A request is made for the control changes generated by the variation in the value of the IED's analog channels.

40	0	Analog Output Status – All variations

The relay is asked about the state at that precise moment of the value of the IED's analog outputs.

41	2	16-Bit Analog Output Block

The relay is asked about the state at that precise moment of the value of the IED's 16-bit analog outputs.

50	1	Time and Date

The IED's date and time are synchronized.

52	2	Time Delay Fine

The relay is asked about the communications delay time. It is measured from the time the relay receives the first bit of the first byte of the question until the transmission of the first bit of the first byte of the IED's response.

60	1	Class 0 Data
60	2	Class 1 Data
60	3	Class 2 Data
60	4	Class 3 Data

The relay is asked about the various data defined in the relay as Class 0, Class 1, Class 2 and Class 3.

Within these requests, the IED's generation and sending of Unsolicited Messages for each of the different kinds of data is tested.

80	1	Internal Indications

The IED's Internal Indication bit (IIN1-7 bit Device Restart) is reset.

--	--	No Object (Cold Start)

When the IED receives a “Cold Load Pickup” object, it must answer with a message object “Time Delay Fine” and with a reset of the internal indication bit IIN1-7 (Device Restart).

--	--	No Object (Warm Start)

When the IED receives a “Warm Load Pickup” object, it must answer with a message object “Time Delay Fine” and with a reset of the internal indication bit IIN1-7 (Device Restart).

--	--	No Object (Delay Measurement)

The IED must answer with a communications object “Time Delay Fine.”

The Broadcast addresses are tested and the indications corresponding to “All Stations” with each of them.

3.35 Alarm Codes

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3.35.2 Activation of Signal and Alarm Generation Event.. 3.35-2
3.35.3 Update of the Alarm Status Magnitude 3.35-2
3.35.4 Indication on the HMI Stand-By Screen... 3.35-3
3.35.5 General Alarm Counter 3.35-3

3.35.1 Introduction

DLX models notify the occurrence of alarms by 3 routes:

- Activation of an Alarm Generation Signal and Event.
- Update of the Alarm Status Magnitude.
- Indication on the HMI Stand-by Screen.
- General Alarm Counter.

3.35.2 Activation of Signal and Alarm Generation Event

The IED has 2 digital signals to indicate critical and non-critical level alarms:

- Non-critical system error: ERR_NONCRIT
- Critical system error: ERR_CRIT

The activation of any of these signals generates its associated event. These signals can be used as inputs to be processed by the user-developed algorithms. Likewise, these signals can be connected to any of the communications protocols for their remote notification.

3.35.3 Update of the Alarm Status Magnitude

The IED has a magnitude whose value is determined by the combination of active alarms in the IED. This magnitude can be used as input to be processed by the user-developed algorithms. Likewise, a user-developed algorithm can connect this magnitude or the outcome of its processing to any of the communications protocols for transmission. Next Table shows the possible causes of alarm coded by alarm magnitude, together with their level of severity.

Table 3.35-1:Alarm Status Magnitude and Severity Level

Alarm	Value	Severity
Error Read Settings	0x00000001	CRITICAL
Non-Calibrated Relay	0x00000010	NON-CRITICAL
Protection Operation Error	0x00000020	CRITICAL
Error Write Settings	0x00000040	CRITICAL
Non-Critical Error in A/D Converter	0x00000080	NON-CRITICAL
Critical Error in A/D Converter	0x00000100	CRITICAL
Loss of Content in Non-Volatile RAM	0x00000200	NON-CRITICAL
Error in Internal Clock Operation	0x00000400	NON-CRITICAL
Digital I/O Operation Error	0x00002000	CRITICAL
Error Read/Write from FLASH	0x00008000	CRITICAL
Error Lack of VDC	0x00080000	CRITICAL
Error IEC 61850	0x00100000	NON-CRITICAL
Error Signals	0x00200000	CRITICAL
Error in Configuration	0x00800000	NON-CRITICAL
Program Error	0x01000000	CRITICAL
Communications Port Error	0x10000000	NON-CRITICAL

In the case of more than one alarm at once, the sum of the codes of these alarms is seen in hexadecimal form.

3.35.4 Indication on the HMI Stand-By Screen

The activation of the Critical System Error signal produces the display of the current magnitude of the status of alarms of the IED in hexadecimal format on the stand-by display of the HMI.

3.35.5 General Alarm Counter

The relay is provided with three counters on the HMI to inform on the number of starts, re-starts and Traps:

- Number of starts (NARRANQS) Informs on the number of times the relay has been cold restarted (relay power supply failure).
- Number of restarts (NREARRAQS) Informs on the number of times the relay has been hot restarted (manually through change in configuration, or change of any nominal setting or relay reset).
- Number of Traps (NTRAPS) Number of exceptions produced in the relay followed by a reset.

Warning: contact the manufacturer if the unit displays any of these alarm codes or Traps counter increment.

3.36 Current Transformers Dimensioning

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3.36.2	CT Dimensioning According to Different Standards	3.36-2
3.36.2.a	Class P of IEC 61869-2 Standard	3.36-2
3.36.2.b	Class C of IEEE C57.13 Standard	3.36-3
3.36.2.c	Class X of BS3938 Standard or Class PX of IEC61869-2	3.36-4
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3.36.3.b	Ktf Factor	3.36-7

3.36.1 Introduction

When dimensioning the Current Transformers (CTs), several factors are taken into account that influence the level of flux generated in the CT itself and, therefore, the tendency of the same to saturate. These include: load, internal resistance, incidence angle of the fault, primary and secondary time constants, remanence, etc.

The following points describe the data provided by different CT standards and the factors that must be calculated for the CT dimensioning

3.36.2 CT Dimensioning According to Different Standards

3.36.2.a Class P of IEC 61869-2 Standard

The CT is specified with the following data:

- Rated transformation ratio: the ratio of the rated primary current to the rated secondary current, e.g 600/5.
- Rated power: power provided by the CT at rated current and rated burden, e.g 10 VA.
- Accuracy class: 5P and 10P defines a maximum composite error of 5% or 10% at the accuracy limit current (accuracy limit factor (ALF) multiplied by the rated current).
- Accuracy limit factor: times the rated current, without DC offset, at which the accuracy class is fulfilled.
- Secondary internal resistance.

The CT will be adequate if K_total=Kssc*Kb*Ktf*Krem<ALF, where

Kssc: symmetrical short-circuit current factor.
Kb: burden factor.
Ktf: overdimensioning factor for DC offset.
Krem: remanence overdimensioning factor.

- **Symmetrical Short-Circuit Current Factor (Kssc)**

It is the ratio between the maximum short circuit current and the rated current.

- **Burden Factor (Kb)**

It is the ratio (Rct+Rburden)/(Rct+Rn), where:

Rn is the rated burden. Rn can be calculated from the CT rated power:

$$Rn = \frac{Pn}{I2n^2}$$

Rct: is the internal secondary resistance of the CT
Rburden: is the burden resistance
I2n: is the rated secondary current

The accuracy limit factor is defined for the rated burden. For a different burden the maximum symmetrical current that assures the fulfillment of the accuracy class will be different than the accuracy limit current (it will be higher than the accuracy limit current if the burden is lower than the rated one and it will be lower if the burden is higher than the rated one). This condition is taken into account by the burden factor.

- **Transient Overdimensioning Factor (Ktf)**

The flux created by a current with DC offset (asymmetrical current) is much higher than the flux generated by a current without any DC component (symmetrical current). As the ALF factor is defined for a symmetrical current, an overdimensioning factor for asymmetrical currents must be considered. This factor will be given by $\frac{\phi_{\text{MAX AC+DC}}}{\phi_{\text{MAX AC}}}$,which represents the ratio between the maximum total flux (sum of DC and AC fluxes) and the maximum AC flux. Ktf is calculated with the following formula:

$$Ktf = \frac{w \cdot T1 \cdot T2}{T1 - T2} \cdot \cos\theta \cdot (e^{\frac{-t}{T1}} - e^{\frac{-t}{T2}}) + \sin\theta \cdot e^{\frac{-t}{T2}} - \sin(wt + \theta) \qquad (3.36.1)$$

, where

T1 is the primary time constant.
T2 is the secondary time constant.
t is the saturation free time or time to saturation.
θ is the fault inception angle.

For saturation free times higher than 15 ms, the maximum flux will be obtained with $\theta = 0$, however, for saturation free times lower than 15 ms, the maximum flux will be obtained for other fault inception angles.

For each saturation free time tolerated by the protection function the worst inception angle should be determined.

- **Remanence Overdimensioning Factor (Krem)**

The remanent flux may worsen the CT transient response if it has the same sign of the flux generated by the current magnitude, burden value and DC offset. This is considered by the remanence overdimensioning factor $Krem = \frac{1}{(1 - Kr)}$, where Kr is the remanent factor (maximum remanent flux / saturation flux).

3.36.2.b Class C of IEEE C57.13 Standard

The most common accuracy class in the IEEEC57.13 standard is the C class. The letter C is followed by a number that indicates the secondary voltage rating, which is defined as the CT secondary voltage that the CT will deliver when it is connected to a standard secondary burden at 20 times the rated secondary current, without exceeding a 10% ratio error. The common standard burdens for protection CTs are 1, 2, 4 and 8 ohms, which correspond, at 5 A rated current, to 100, 200, 400 and 800 V secondary rating voltages (for a C100 CT the voltage at the 1 ohm burden will be 20*5*1=100 V).

With the secondary voltage rating (burden voltage - Vb) we can obtain the internal magnetizing voltage by adding the voltage drop in the secondary resistance (Rct):

Emrated=Vb+Rct*20*I2n

The dimensioning of an IEEE CT can be done by calculating Em as:

Emcalc=Ktotal'*I2n*(Rct+Rb),

where Ktotal'=Kssc*Ktf*Krem.

If Emcalc<Emrated= Vb+Rct*20*I2n the CT will be valid

An easier deduction can be made considering that the ALF factor of a C class CT is always 20 (the 10% ratio error cannot be exceeded for a secondary current 20 times the rated current with the rated burden). If Ktotal<ALF the CT will be valid.

3.36.2.c Class X of BS3938 Standard or Class PX of IEC61869-2

Class X CT is defined with:

- Primary and secondary rated currents.
- Transformation ratio.
- Rated knee-point voltage.
- Magnetizing current at rated knee-point voltage.
- Resistance of secondary winding.

The rated knee-point voltage is defined as the minimum voltage, at rated frequency, applied to the CT secondary terminals which increased by a 10% causes an increase in the magnetizing current of 50% (see Figure 3.36.1).

The relationship between the rated knee-point voltage (Vknee) and the magnetizing voltage at the accuracy limit current with rated burden (Emrated) is done by approximation, because the definition of the two voltages has no direct relation (Vknee has to do with the slope of the magnetizing characteristic and Emrated with the current composite error). It is normally considered that Emrated=(1.25 – 1.3)*Vknee.

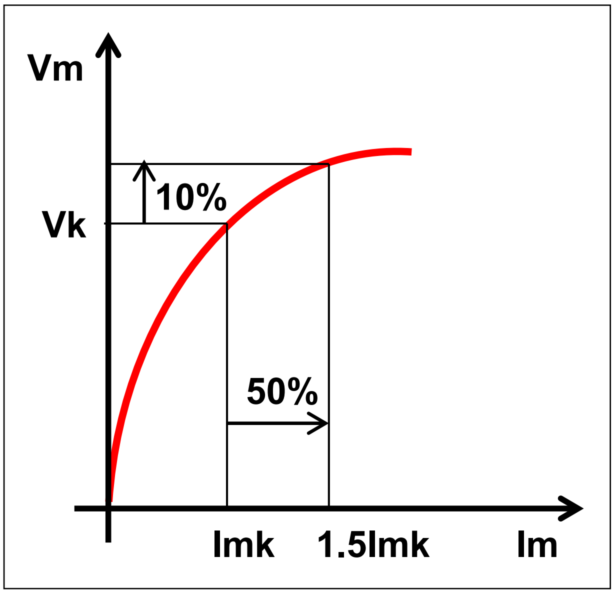

Figure 3.36.1 Knee Point Voltage Definition.

Once Emrated is calculated it can be compared with Emcalc= Ktotal'*I2n*(Rct+Rb). The CT will be valid if Emcalc<Emrated.

where Ktotal'=Kssc*Ktf*Krem

3.36.3 CT Dimensioning for Different Protection Functions

Table 3.36-1 includes general parameters to be considered for the calculation of CT dimensioning factors.

Table 3.36-2 includes the saturation free times (for Ktf calculation) and current values (for Kssc calculation) that must be used for CT dimensioning.

Table 3.36-1: General Parameters

Data	Description	Units
f	Frequency (50 or 60 Hz)	(Hz)
IF	Maximum primary fault current (single phase fault current or three phase fault current, the highest one). It depends on the protection function – see table 2	(A)
CT ratio	I1n/I2n	
I1n	Primary nominal current	(A)
I2n	Secondary nominal current	(A)
T1	Primary time constant = L/R (taking into account the total impedance from the source to the fault location).	(s)
T2	Secondary time constant (CT time constant) (Usual value = 3 s)	(s)
Rn	CT nominal resistance	(ohms)
Rct	CT internal resistance For CTs of 5 A nominal current, the Rct is around 0.2 ohms to 0.4 ohms. For the CTs of 1 A nominal current, the Rct is higher (10 ohms for example).	(ohms)
Rb	CT burden resistance = Relay burden + Cable resistance	(ohms)
	Cable resistance = 2·RL (if the maximum primary fault current belongs to a single phase fault). Cable resistance = RL (when the maximum primary fault current belongs to a 3 phase fault). RL = ρ · (L/S) ρ = resistivity ($mm^2*\Omega/m$) S = cable section (m^2) L = cable length (m)	(ohms)
	Relay burden = (0.2 VA) / ($I2n^2$)	(ohms)
t	Required saturation free time (depends of the protection function – see table 2)	(s)

Table 3.36-2: Saturation Free Time and Fault Current Values				
Protection Function	**Fault Scenarios to be considered**	**t (s) = the time (seconds) from the fault start until the CT becomes saturated.**		**IF (fault current to calculate Kssc)**
		f = 50 Hz	f = 60 Hz	
87T/87B/87L	External fault in the busbar (giving maximum fault current)	$3x10^{-3}$ (s)	$2.5x10^{-3}$ (s)	$IF = IF_{max\_external}$ Maximum fault current for external fault
87N	External fault in the busbar (giving maximum fault current)	$4x10^{-3}$ (s)	$3.5x10^{-3}$ (s)	$IF = IF_{max\_external}$ Maximum fault current for external fault
50	Internal fault giving a fault current equal to the pick-up value	$10x10^{-3}$ (s)	$8.3x10^{-3}$ (s)	$IF = IF_{pickup50}$ (instantaneous overcurrent unit pickup in primary value). IFpickup50 ≈ 0.7 · (IF_2) IF_2=the fault current to be detected by 50 overcurrent protection. It is normally the fault current at 50%-80% of the feeder. **Note 1**: The 0.7 factor is introduced to compensate CT errors, relay errors and short circuit calculation errors. **Note 2**: If the current IF_2 is not known, a first approximation could be done taking IF_1 instead of IF_2; Being IF_1= 80% of the fault current at 0% of the feeder (maximum short circuit current) = 80% (IF0%)
	Internal fault at 0% of the line	$8.4x10^{-3}$ (s)	$7 x10^{-3}$ (s)	$IF = IF_{0\%}$
21	Internal fault at 0% of the line	$8.4x10^{-3}$ (s)	$7 x10^{-3}$ (s)	$IF = IF_{0\%}$
	Internal fault at 100% of the line	$15x10^{-3}$ (s)	$12.5x10^{-3}$ (s)	$IF = IF_{100\%}$
	Internal fault at the limit of zone 1 reach (normally 80% of the line).	$25x10^{-3}$ (s)	$21x10^{-3}$ (s)	$IF = IF_{80\%}$

3.36.3.a Remanence Factor

If close onto fault conditions may occur, a remanence factor should be considered.

A recommended value may be Kr=50%--> Krem=2

3.36.3.b Ktf Factor

The following tables include different ktf values calculated according to the formula (3.36e formula (3.36.1). The saturation free times included in table 2 are considered together with the worst inception angles (θ). T2 is considered equal to 3 s.

Function	T1 (s)	K_{tf}
87T/87B/87L	0.01-0.3	0.43

Function	T1 (s)	K_{tf}
87N	0.01-0.3	0.58

Function	T1 (s)	K_{tf_pickup} 60 Hz	K_{tf_pickup} 50 Hz	$K_{tf\_0\%}$ 60 Hz	$K_{tf\_0\%}$ 50 Hz
50	0.01	2.91	2.81	2.3	2.3
	≤ 0.02	3.25	3.17	2.6	2.5
	≤ 0.03	3.38	3.33	2.7	2.6
	≤ 0.04	3.46	3.42	2.7	2.7
	≤ 0.05	3.51	3.47	2.7	2.7
	≤ 0.08	3.58	3.56	2.8	2.8
	≤ 0.1	3.61	3.59	2.8	2.8
	≤ 0.2	3.66	3.65	2.8	2.8
	≤ 0.3	3.68	3.67	2.8	2.8

Function	T1 (s)	$K_{tf\ zone1}$ 60 Hz	$K_{tf\ zone1}$ 50 Hz	$K_{tf\ 100\%}$ 60 Hz	$K_{tf\ 100\%}$ 50 Hz	$K_{tf\ 0\%}$ 60 Hz	$K_{tf\ 0\%}$ 50 Hz
21	0.01	4.3	3.9	3.8	3.6	2.3	2.3
	≤ 0.02	5.9	5.5	4.6	4.4	2.6	2.5
	≤ 0.03	6.6	6.3	4.9	4.8	2.7	2.6
	≤ 0.04	7.15	6.8	5.1	5	2.7	2.7
	≤ 0.05	7.46	7.2	5.3	5.2	2.7	2.7
	≤ 0.1	8.14	7.9	5.5	5.5	2.8	2.8
	≤ 0.2	8.5	8.4	5.6	5.6	2.8	2.8
	≤ 0.3	8.6	8.5	5.7	5.7	2.8	2.8

NOTE: For overcurrent and distance functions, Ktotal must be calculated for each of the cases considered (fault at 0% and fault with Ifault=Ipick-up for overcurrent; fault at 0%, 80% and 100% of the line for distance). The maximum value of Ktotal must be used to compare against ALF.

Overcurrent

$$Ktotal_{0\%}=Kssc_{0\%}*Kburden*Ktf_{0\%}*Krem$$

$$Ktotal_{pick\text{-}up}=Kssc_{pick\text{-}up}*Kburden*Ktf_{pick\text{-}up}*Krem$$

$$Ktotal=max(Ktotal_{0\%}, Ktotal_{pick\text{-}up})$$

Distance

$$Ktotal_{0\%}=Kssc_{0\%}*Kburden*Ktf_{0\%}*Krem$$

$$Ktotal_{80\%}=Kssc_{80\%}*Kburden*Ktf_{80\%}*Krem$$

$$Ktotal_{100\%}=Kssc_{100\%}*Kburden*Ktf_{100\%}*Krem$$

$$Ktotal=max(Ktotal_{0\%}, Ktotal_{80\%}, Ktotal_{100\%})$$

A. PROCOME 3.0 Protocol

A.1 Control Application Layer A-A-2

A.2 Control Data A-A-3

A.1 Control Application Layer

- **Application Functions**

☑ **Initialization of the secondary station**
☑ **Clock synchronization**
☑ **Control functions**
- ☑ Control interrogation
- ☑ Refreshing of digital control signals
- ☑ Write outputs
- ☑ Enabling and disabling of inputs
- ☑ Overflow
- ☑ Force single coil

- **Compatible ASDUs in Secondary-to-Primary Direction**

☑	**<5>**	**Identification**
☑	**<6>**	**Clock synchronization**
☑	**<100>**	**Transmission of metering values and digital control signal changes**
☑	**<101>**	**Transmission of counters**
☑	**<103>**	**Transmission of digital control states**
☑	**<110>**	**Write binary outputs**
☑	**<121>**	**Force single coil**

- **Compatible ASDUs in Primary to Secondary Direction**

☑	**<6>**	**Clock synchronization**
☑	**<100>**	**Control data request (Metering values and control changes INF=200)**
☑	**<100>**	**Control data request (Capture of counters INF=202)**
☑	**<100>**	**Control data request (Request for counters INF=201)**
☑	**<103>**	**Request for digital control states**
☑	**<110>**	**Write binary outputs**
☑	**<112>**	**Enable/disable binary inputs**
☑	**<121>**	**Force single coil**

A.2 Control Data

- **Control Metering (MEA-s)**

Configurable through the ***Zivercom***®: any value measured or calculated by the protection or generated by the programmable logic. It is possible to select between primary and secondary values, taking into account the corresponding transformation ratios.

All the full scale values of the magnitudes are definable, and these magnitudes can be used to create **user values**. Some typical values are:

- Phase and sequence currents and harmonics: **Rated value I_{PHASE} + 20**% sends 4095 counts.
- Ground and synchronization currents: **Rated value I_{GROUND} + 20%** sends 4095 counts.
- Sensitive ground and directional ungrounded neutral currents: **1.2 A** sends 4095 counts.
- Line-to-neutral and sequence voltages and harmonics: **(Rated value V / √3) + 20%** sends 4095 counts.
- Phase-to-phase and polarization voltages: **Rated value V + 20%** sends 4095 counts.
- Powers: 3 x 1.4 x Rated value I_{PHASE} x Rated value / √3 sends 4095 counts.
- Power factor: from **–1** to **1** sends from –4095 to 4095 counts.
- Frequency: from **0 Hz** to **1.2 x Frequency_{RATED}** (50Hz / 60Hz) sends 4095 counts.
- Thermal value: **240%** sends 4095 counts
- Distance to the fault:
  - Percentage value: **±100%** sends ±4095 counts (range from -100% to 100%).
  - Value in kilometers: with the "**length of the line**," it sends ±4095 counts (range from 0 km to the length of the line set in km. It can also send negative values).
  - Value in miles: with the "**length of the line**," it sends ±4095 counts (range from 0 km to the length of the line set in miles. It can also send negative values).

With the ***Zivercom***® program, it is possible to define the full-scale value to be used to transmit this magnitude in counts, the unit that all the protocols use. There are three definable parameters that determine the range of distance covered:

- **Offset value**: the minimum value of the magnitude for which 0 counts are sent.
- **Limit**: the length of the range of the magnitude on which it is interpolated to calculate the number of counts to send. If the offset value is 0, it coincides with the value of the magnitude for which the defined maximum of counts (4095) is sent.
- **Nominal flag**: this flag allows determining whether the limit set is proportional to the rated value of the magnitude or not. The rated value of the new magnitudes defined by the user in the programmable logic can be configured, while the rest of the existing magnitudes are fixed.

The expression that allows defining this full-scale value is the following:

- -When the Nominal flag is enabled,

$$CommunicationsMeasurement = \frac{Measurement - Offset}{Nominal} \times \frac{4095}{Limit}$$

- -When the Nominal flag is NOT enabled,

$$CommunicationsMeasurement = (Measurement - Offset) \times \frac{4095}{Limit}$$

- **Counters**

Configurable through the ***Zivercom***®: Counters can be created with any signal configured in the programmable logic or from the protection modules. The default counters are those of the real energies (positive and negative) and the reactive energies (capacitive and inductive).

The metering range of energies in primary values is from 100wh/varh to 99999 MWh/Mvarh. The magnitude transmitted via communications is this same primary value; that is, one (1) count represents 100 wh/varh.

- **Force Single Coil (ISE-s)**

Configurable through the ***Zivercom***®: A command can be made on any input from the protection modules and on any signal configured in the programmable logic.

- **Write Control Outputs (ISS-s)**

Configurable through the ***Zivercom***®: A writing can be made on any input from the protection modules and on any signal configured in the programmable logic.

- **Digital Control Signals (ISC-s)**

Configurable through the ***Zivercom***®: Any input or output logic signal from the protection modules or generated by the programmable logic.

B. DNP V3.00 Device Profiles Document

DNP V3.0

DEVICE PROFILE DOCUMENT

This document must be accompanied by: **Implementation Table** and **Point List**.

Vendor Name: **ZIV Aplicaciones y Tecnología S.A.**

Device Name: **DLX**

Highest DNP Level Supported:	Device Function:
For Requests 2 For Responses 2	☐ Master ☒ Slave

Notable objects, functions, and/or qualifiers supported in addition to the Highest DNP Levels Supported (the complete list is described in the attached table):

1) Supports Enable/Disable Unsolicited Responses (FC=20 and 21), for classes 1 and 2.
2) Supports Write operations (FC=2) on Time and Date objects.
3) Supports Delay measurement Fine (FC=23).
4) Supports Warm Start command (FC=14).
5) Supports **Unsolicited after Restart (for compatibility with terminals whose revision is before DNP3-1998)**
6) Supports selection of DNP3 Revision.
7) Supports indication of no **synchronization in time.**
8) Supports simultaneous communications with two different Master devices
9) Supports assign event Class for Binary, Analog and Counter events: Class 1 , Class 2, Class 3, None
10) Supports respond to Multiple Read Request with multiple object types in the same Application Fragment .

Maximum Data Link Frame Size (octets):	Maximum Application Fragment Size (octets):
Transmitted 292 Received 292	Transmitted 2048 (if >2048, must be configurable) Received 249 (must be <= 249)

Maximum Data Link Re-tries:	Maximum Application Layer Re-tries:
☒ None ☐ Fixed at ________________ ☐ Configurable, range ___ to _____	☐ None ☒ Configurable, range 0 to 3 (Fixed is not permitted)

Requires Data Link Layer Confirmation:

☒ Never
☐ Always
☐ Sometimes. If 'Sometimes', when?
____
☐ Configurable. If 'Configurable', how?
____

Requires Application Layer Confirmation: ☐ Never ☐ Always (not recommended) ☒ When reporting Event Data (Slave devices only) For unsolicited, Class 1 Class 2 and Class 3 responses that contain Event Data. (If there is no Event Data reported into a Class 1 2 or 3 response, Application Layer Confirmation is not requested) ☐ When sending multi-fragment responses (Slave devices only) ☐ Sometimes. If 'Sometimes', when? ☐ Configurable. If 'Configurable', how?
Timeouts while waiting for: Data Link Confirm ☒ None ☐ Fixed at ____ ☐ Variable ☐ Configurable Complete Appl. Fragment ☒ None ☐ Fixed at ____ ☐ Variable ☐ Configurable Application Confirm ☐ None ☐ Fixed at ____ ☐ Variable ☒ Configurable Complete Appl. Response ☒ None ☐ Fixed at ____ ☐ Variable ☐ Configurable Others ______________________________ Attach explanation if 'Variable' or 'Configurable' was checked for any timeout Application Confirm timeout setting (***MMI***): Range 50 ms. 65.535 ms.

Sends/Executes Control Operations:

- Maximum number of CROB (obj. 12, var. 1) objects supported in a single message __1
- Maximum number of Analog Output (obj. 41, any var.) supported in a single message__0

☐ Pattern Control Block and Pattern Mask (obj. 12, var. 2 and 3 respectively) supported.

☐ CROB (obj. 12) and Analog Output (obj. 41) permitted together in a single message.

WRITE Binary Outputs	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
SELECT (3) / OPERATE (4)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE (5)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE - NO ACK (6)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Count > 1	☐ Never	☐ Always	☒ Sometimes	☐ Configurable
Pulse On	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Pulse Off	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Latch On	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Latch Off	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Queue	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
Clear Queue	☒ Never	☐ Always	☐ Sometimes	☐ Configurable

Attach explanation:

- All points support the same Function Codes: (3) Select, (4) Operate, (5) Direct Operate and (6) Direct Operate - No ACK.
- Maximum Select/Operate Delay Time: 60 seconds.
- Count can be >1 only for PULSE ON and PULSE OFF

FILL OUT THE FOLLOWING ITEMS FOR SLAVE DEVICES ONLY:	
Reports Binary Input Change Events when no specific variation requested: ☐ Never ☒ Only time-tagged ☐ Only non-time-tagged ☐ Configurable to send both, one or the other (attach explanation)	Reports time-tagged Binary Input Change Events when no specific variation requested: ☐ Never ☒ Binary Input Change With Time ☐ Binary Input Change With Relative Time ☐ Configurable (attach explanation)
Sends Unsolicited Responses: ☐ Never ☒ Configurable (See Note D) ☒ Only certain objects (Class 1 2 and 3) ☐ Sometimes (attach explanation) ☒ ENABLE/DISABLE UNSOLICITED Function codes supported	Sends Static Data in Unsolicited Responses: ☒ Never ☐ When Device Restarts ☐ When Status Flags Change No other options are permitted.
Default Counter Object/Variation: ☐ No Counters Reported ☐ Configurable (attach explanation) ☒ Default Object _20,21____ Default Variation ______1_____ ☐ Point-by-point list attached	Counters Roll Over at: ☐ No Counters Reported ☐ Configurable (attach explanation) ☐ 16 Bits ☐ 32 Bits ☒ Other Value ____31 Bits____ ☐ Point-by-point list attached
Sends Multi-Fragment Responses: ☒ Yes ☐ No	

QUICK REFERENCE FOR DNP3.0 LEVEL 2 FUNCTION CODES & QUALIFIERS

Function Codes

1	Read
2	Write
3	Select
4	Operate
5	Direct Operate
6	Direct Operate-No ACK
7	Immediate Freeze
8	Immediate Freeze no ACK
13	Cold Start
14	Warm Start
20	Enable Unsol. Messages
21	Disable Unsol. Messages
23	Delay Measurement
129	Response
130	Unsolicited Message

7	6	5	4	3	2	1	0
	Index Size			Qualifier Code			

Index Size

0- No Index, Packed
1- 1 byte Index
2- 2 byte Index
3- 4 byte Index
4- 1 byte Object Size
5- 2 byte Object Size
6- 4 byte Object Size

Qualifier Code

0- 8-Bit Start and Stop Indices
1- 16-Bit Start and Stop Indices
2- 32-Bit Start and Stop Indices
3- 8-Bit Absolute address Ident.
4- 16-Bit Absolute address Ident.
5- 32-Bit Absolute address Ident.
6- No Range Field (all)
7- 8-Bit Quantity
8- 16-Bit Quantity
9- 32-Bit Quantity
11-(0xB) Variable array

IMPLEMENTATION TABLE

OBJECT			REQUEST (DLX parse)		RESPONSE (DLX respond)		
Obj	**Var**	**Description**	**Func Codes (dec)**	**Qual Codes (hex)**	**Func Codes (dec)**	**Qual Codes (hex)**	**Notes**
1	0	Binary Input – All variations	1	0,1,6,7,8			Assigned to Class 0.
1	1	Binary Input	1	0,1,6,7,8	129	0,1	
2	0	Binary Input with Status	1	0,1,6,7,8	129	0,1	
2	0	Binary Input Change – All variations	1	6,7,8			
2	2	Binary Input Change with Time	1	6,7,8	129,130	17,,28	Assign to Event Class
12	1	Control Relay Output Block	3,4,5,6	17,28	129	17,28	Echo of request
20	0	Binary Counter – All variations	1	0,1,6,7,8			Assigned to Class 0.
20	1	32 Bits Binary Counter			129	0,1	
21	0	Frozen Counter – All variations	1	0,1,6,7,8			
21	1	32 Bits Frozen Counter			129	0,1	
22	0	Counter Change Event – All variations	1	6,7,8			
22	5	32 Bits Counter Change Event With Time			129,130	17,,28	Assign to Event Class
30	0	Analog Input – All variations	1	0,1,6,7,8			Assigned to Class 0.
30	1	32-Bit Analog Input	1	0,1,6,7,8	129	1	
30	2	16-Bit Analog Input	1	0,1,6,7,8	129	1	
32	0	Analog Change Event – All variations	1	6,7,8			
32	3	32-Bit Analog Change Event with Time	1	6,7,8	129,130	28	Assign to Event Class
32	4	16-Bit Analog Change Event with Time	1	6,7,8	129,130	28	Assign to Event Class
50	1	Time and Date	2	7 count=1	129		C
52	2	Time Delay Fine	23		129	1	F,G

OBJECT			REQUEST (DLX parse)		RESPONSE (DLX respond)		
Obj	Var	Description	Func Codes (dec)	Qual Codes (hex)	Func Codes (dec)	Qual Codes (hex)	Notes
60	1	Class 0 Data	1	6	129	1	
60	2	Class 1 Data	1 20,21	6,7,8 6	129,130	28	D
60	3	Class 2 Data	1 20,21	6,7,8 6	129,130	28	D
60	4	Class 3 Data	1 20,21	6,7,8 6	129,130	28	D
80	1	Internal Indications	2	0 index=7			E
--	--	No Object (Cold Start)	13				F
--	--	No Object (Warm Start)	14				F
--	--	No Object (Delay Measurement)	23				G

NOTES

C: Device supports write operations on Time and Date objects. Time Synchronization-Required Internal Indication bit (IIN1-4) will be cleared on the response.

D: The device can be configured to send or not, unsolicited responses depending on a configuration option by means of ***MMI*** (Man-Machine Interface or front-panel user interface ***ZIVercomPlus***). Then, the Master can Enable or Disable Unsolicited messages (for Classes 1, 2 and 3) by means of requests (FC 20 and 21).
If the unsolicited response mode is configured “on”, then upon device restart, the device will transmit an initial Null unsolicited response, requesting an application layer confirmation. While waiting for that application layer confirmation, the device will respond to all function requests, including READ requests.

E: Restart Internal Indication bit (IIN1-7) can be cleared explicitly by the master.

F: The outstation, upon receiving a ***Cold or Warm Start*** request, will respond sending a Time Delay Fine object message (which specifies a time interval until the outstation will be ready for further communications), restarting the DNP process, clearing events stored in its local buffers and setting IIN1-7 bit (Device Restart).

G: Device supports Delay Measurement requests (FC = 23). It responds with the Time Delay Fine object (52-2). This object states the number of milliseconds elapsed between Outstation receiving the first bit of the first byte of the request and the time of transmission of the first bit of the first byte of the response.

DEVICE SPECIFIC FEATURES

- Internal Indication IIN1-6 (Device trouble): **Set to indicate a change in the current DNP configuration in the outstation. Cleared in the next response. Used to let the master station know that DNP settings have changed at the outstation. Note that some erroneous configurations could make impossible to communicate this condition to a master station.**

  This document also states the DNP3.0 settings currently available in the device. If the user changes whatever of these settings, it will set the *Device Trouble Internal Indication* bit on the next response sent.
- Event buffers**: device can hold as much as 128** Binary Input Changes**,** 64 Analog Input Changes and 64 Counter Input Change. **If these limits are reached the device will set the *Event Buffers Overflow Internal Indication* bit on the next response sent. It will be cleared when the master reads the changes, making room for new ones.**
- Configuration ➔ Operation Enable **menu: the device can enable or disable** permissions **for the operations over al Control Relay Output Block. In case permissions are configured off (disabled) the response to a command (issued as Control Relay Output Block) will have the Status code NOT_AUTHORIZED. In case the equipment is** blocked **the commands allowed are the configured when permitted. While blocked, the relay will accept commands over the configured signal. If the equipment is in** operation inhibited state**, the response to all commands over the configured signal will have the Status code NOT_AUTHORIZED.**
- **Customers can configure Inputs/Outputs to suit their needs, by means of** *ZIVercomPlus®* **software.**

POINT LIST

BINARY INPUT (OBJECT 1) -> Assigned to Class 0. BINARY INPUT CHANGE (OBJECT 2) -> Assign to Class.		
Index	Description	
0	*Configure by ZIVercomPlus®* 2048 points	
1	*Configure by ZIVercomPlus®* 2048 points	
2	*Configure by ZIVercomPlus®* 2048 points	
3	*Configure by ZIVercomPlus®* 2048 points	
4	*Configure by ZIVercomPlus®* 2048 points	
5	*Configure by ZIVercomPlus®* 2048 points	
6	*Configure by ZIVercomPlus®* 2048 points	
7	*Configure by ZIVercomPlus®* 2048 points	
8	*Configure by ZIVercomPlus®* 2048 points	
9	*Configure by ZIVercomPlus®* 2048 points	
10	*Configure by ZIVercomPlus®* 2048 points	
11	*Configure by ZIVercomPlus®* 2048 points	
12	*Configure by ZIVercomPlus®* 2048 points	
13	*Configure by ZIVercomPlus®* 2048 points	
14	*Configure by ZIVercomPlus®* 2048 points	
15	*Configure by ZIVercomPlus®* 2048 points	
16	*Configure by ZIVercomPlus®* 2048 points	
17	*Configure by ZIVercomPlus®* 2048 points	
...	*Configure by ZIVercomPlus®* 2048 points	
253	*Configure by ZIVercomPlus®* 2048 points	
254	*Configure by ZIVercomPlus®* 2048 points	
255	*Configure by ZIVercomPlus®* 2048 points	

CONTROL RELAY OUTPUT BLOCK (OBJECT 12)		
Index	Description	
0	*Configure by ZIVercomPlus®* 256 points	
1	*Configure by ZIVercomPlus®* 256 points	
2	*Configure by ZIVercomPlus®* 256 points	
3	*Configure by ZIVercomPlus®* 256 points	
4	*Configure by ZIVercomPlus®* 256 points	
5	*Configure by ZIVercomPlus®* 256 points	
6	*Configure by ZIVercomPlus®* 256 points	
7	*Configure by ZIVercomPlus®* 256 points	
8	*Configure by ZIVercomPlus®* 256 points	
9	*Configure by ZIVercomPlus®* 256 points	
10	*Configure by ZIVercomPlus®* 256 points	
11	*Configure by ZIVercomPlus®* 256 points	
12	*Configure by ZIVercomPlus®* 256 points	
13	*Configure by ZIVercomPlus®* 256 points	

CONTROL RELAY OUTPUT BLOCK (OBJECT 12)		
Index	**Description**	
14	*Configure by ZIVercomPlus®* 256 points	
15	*Configure by ZIVercomPlus®* 256 points	
16	*Configure by ZIVercomPlus®* 256 points	
17	*Configure by ZIVercomPlus®* 256 points	
...	*Configure by ZIVercomPlus®* 256 points	
253	*Configure by ZIVercomPlus®* 256 points	
254	*Configure by ZIVercomPlus®* 256 points	
255	*Configure by ZIVercomPlus®* 256 points	

ANALOG INPUT (OBJECT 30) -> Assigned to Class 0. ANALOG INPUT CHANGE (OBJECT 32) -> Assign to Class		
Index	**Description**	**Deadband**
0	*Configure by ZIVercomPlus®* 256 points	Deadband_1.
1	*Configure by ZIVercomPlus®* 256 points	Deadband_2.
2	*Configure by ZIVercomPlus®* 256 points	Deadband_3.
3	*Configure by ZIVercomPlus®* 256 points	Deadband_4.
4	*Configure by ZIVercomPlus®* 256 points	Deadband_5.
5	*Configure by ZIVercomPlus®* 256 points	Deadband_6.
6	*Configure by ZIVercomPlus®* 256 points	Deadband_7.
7	*Configure by ZIVercomPlus®* 256 points	Deadband_8.
8	*Configure by ZIVercomPlus®* 256 points	Deadband_9.
9	*Configure by ZIVercomPlus®* 256 points	Deadband_10.
10	*Configure by ZIVercomPlus®* 256 points	Deadband_11.
11	*Configure by ZIVercomPlus®* 256 points	Deadband_12.
12	*Configure by ZIVercomPlus®* 256 points	Deadband_13.
13	*Configure by ZIVercomPlus®* 256 points	Deadband_14.
14	*Configure by ZIVercomPlus®* 256 points	Deadband_15.
15	*Configure by ZIVercomPlus®* 256 points	Deadband_16.

Additional assign with ***ZIVercomPlus***⑧:

Index	Description
16	***Configure by ZIVercomPlus⑧ 256 points***
17	***Configure by ZIVercomPlus⑧ 256 points***
18	***Configure by ZIVercomPlus⑧ 256 points***
19	***Configure by ZIVercomPlus⑧ 256 points***
20	***Configure by ZIVercomPlus⑧ 256 points***
21	***Configure by ZIVercomPlus⑧ 256 points***
22	***Configure by ZIVercomPlus⑧ 256 points***
23	***Configure by ZIVercomPlus⑧ 256 points***
24	***Configure by ZIVercomPlus⑧ 256 points***
25	***Configure by ZIVercomPlus⑧ 256 points***
26	***Configure by ZIVercomPlus⑧ 256 points***
27	***Configure by ZIVercomPlus⑧ 256 points***
....	***Configure by ZIVercomPlus⑧ 256 points***
62	***Configure by ZIVercomPlus⑧ 256 points***
63	***Configure by ZIVercomPlus⑧ 256 points***

The full scale ranges are adjustable and user's magnitudes can be created. It's possible to choose between primary and secondary values, considering CT and PT ratios. Typical ranges in secondary values are:

Description	**Full Scale Range**		
	Engineering units	**Counts**	
Currents (Phases, sequences, harmonics)	0 to 1,2 x In_{PHASE} A	0 to 32767	**◊Deadband**
Currents (Ground, polarizing)	0 to 1,2 x In_{GROUND} A	0 to 32767	**◊Deadband**
Currents (Ground sensitive, isolated neutral)	0 to 1,2 A	0 to 32767	**◊Deadband**
Voltages (Phase to ground, sequences, harmonics)	0 to 1,2 x Vn/√3 V	0 to 32767	**◊Deadband**
Voltages(Phase to phase, synchronizing)	0 to 1,2 x Vn V	0 to 32767	**◊Deadband**
Power (Real, reactive, apparent)	0 to 3 x 1,4 x In_{PHASE} x Vn/√3 W	-32768 to 32767	**◊Deadband**
Power factor	-1 to 1	-32768 to 32767	**◊Deadband**
Frequency	0 to 1,2 x Rated frequency (50/60 Hz)	0 to 32767	**◊Deadband**
Thermal value	0 to 200%	0 to 32767	**◊Deadband**
Distance to Fault - **Percentage of line length:** 100% sends 32767 counts (range from -100% to 100%) - **Distance in kilometers:** with the "line length" sends 32767 counts (range from - "line length" to the "line length" set in km) - **Distance in miles:** with the "line length" sends 32767 counts (range from - "line length" to the "line length" set in miles)		-32768 to 32767	**◊Deadband**

Communication Measure in Counts

With ***ZIVercomPlus*** program is possible to define the ***Full Scale Range*** that is desired to transmit each magnitude in *counts*. Parameters necessary to configure the Mathematical expression are:

- **Offset:** A number indicating the compensation of de Magnitude.
- **Limit:** it's the Maximum value of magnitude range.
- **Max Communication:** it's a constant that depend of the Number Bits of Analog Input.
  Max Communication=2(Number Bits Analog Input - 1)**
  For 16-Bit Analog Input (Obj 30 Var. 2)   2**(15) =   32.767 counts
  For 32-Bit Analog Input (Obj 30 Var. 1)   2**(31) = 2.147.483.647 counts
- **Rated value:** Nominal Value of the magnitude.
- **Nominal Flag:** This *flag* defines if the **limit** is proportional to the **rated value** of the magnitude.
- **TR:** Secondary to Primary Transformation Ratio.

Mathematical expression to describe the ***Full Scale Range*** is:

- When **Nominal Flag** is actived,

$$MeasureCom = TR \times \frac{Measure - Offset}{RatedValue} \times \frac{MaxComunication}{Limit}$$

- When **Nominal Flag** is NOT actived,

$$MeasureCom = TR \times (Measure - Offset) \times \frac{MaxComunication}{Limit}$$

Communication Measure in Engineering Units

With ***ZIVercomPlus*** program **also** it's possible to transmit each magnitude in Engineering Units. Parameters necessary to configure the Mathematical expression are:

- **Offset:** A number indicating the compensation of de magnitude.
- **Limit:** it's the Maximum value of magnitude range.
- **Rated value:** Nominal Value of the magnitude.
- **Nominal Flag:** this *flag* defines if the **limit** is proportional to the **rated value** of the magnitude or not. The rated value of the new magnitudes defined by the user is a setting, while for the pre-defined magnitudes is a fix value.
- **TR:** Secondary to Primary Transformation Ratio.
- **Scaling Factor:** Multiply Factor of magnitude.

Mathematical expression to obtain **Measure in Engineering Units** is:

- When **Nominal Flag** is actived,

$$MeasureCom = TR \times \frac{Measure - Offset}{RatedValue} \times ScalingFactor$$

- When **Nominal Flag** is NOT actived,

$$MeasureCom = TR \times (Measure - Offset) \times ScalingFactor$$

DeadBands

- Deadband is an area of a magnitude range or band where no generate magnitude change (the magnitude is dead). Meaning that no generation of Analogical Change Events if difference with value of generation of previous change is not equal or greater that DeadBand calculated. There is an independent setting for each 16 Measures with change.
- A Deadband is calculated as a percentage defined in DeadBand Setting over value of **parameter Limit**.
- The Deadband can be adjusted to the device by means of ***MMI*** (Man-Machine Interface or front-panel user interface *ZIVercomPlus*), between 0.0000% and 100.00%, in steps of 0.0001%. Default value is 100.00%, meaning that generation of Analog Change Events is **DISABLED** for that input. There is an independent setting for each Magnitude with change.

BINARY COUNTER (OBJECT 20) -> Assigned to Class 0. FROZEN COUNTER (OBJECT 21) 32 BIT COUNTER CHANGE EVENT (OBJECT 22) -> Assign to Class		
Index	Description	Deadband
0	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_1.
1	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_2.
2	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_3.
3	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_4.
4	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_5.
5	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_6
6	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_7.
7	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_8.
8	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_9.
9	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_10.
10	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_11.
11	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_12.
12	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_13.
13	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_14.
14	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_15.
15	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_16.
16	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_17.
17	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_18.
18	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_19.
19	*Configure by ZIVercomPlus® 256 points*	CounterDeadBand_20.

CounterDeadBands

- CounterDeadband is an area of a counter magnitude range or band, where no generate counter magnitude change (the communication counter magnitude is dead).Meaning that no generation of Counter Change Events if difference with value of generation of previous change is not equal or greater that CounterDeadBand setting. There is an independent setting for each Counter.

- The CounterDeadband can be adjusted to the device by means of ***MMI*** (Man-Machine Interface or front-panel user interface *ZIVercomPlus*), between 1 and 32767, in steps of 1, default value is 1.

DNP3 PROTOCOL SETTINGS

DNP3 Protocol Settings						
DNP Protocol Configuration						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step/ Select**	**Unit**
Relay Number	Integer	0	65519	1	1	
T Confirm Timeout	Integer	1000	65535	1000	1	msec.
Max Retries	Integer	0	65535	0	1	
Enable Unsolicited.	Boolean	0 (No)	1 (Yes)	0 (No)	1	
Enable Unsol. after Restart	Boolean	0 (No)	1 (Yes)	0 (No)	1	
Unsolic. Master No.	Integer	0	65519	1	1	
Unsol. Grouping Time	Integer	100	65535	1000	1	msec.
Synchronization Interval	Integer	0	120	0	1	min.
DNP 3.0 Rev.	Integer	2003 ST.ZIV	2003 ST.ZIV	2003	2003 ST.ZIV	
Binary Changes CLASS	Integer	None Class 1 Class 2 Class 3	None Class 1 Class 2 Class 3	Class 1	None Class 1 Class 2 Class 3	
Analog Changes CLASS	Integer	None Class 1 Class 2 Class 3	None Class 1 Class 2 Class 3	Class 2	None Class 1 Class 2 Class 3	
Counter Changes CLASS	Integer	None Class 1 Class 2 Class 3	None Class 1 Class 2 Class 3	Class 3	None Class 1 Class 2 Class 3	
Binary Status Change	Boolean	0 (No)	1 (Yes)	1 (Yes)	1	
32 Bits Analog Input	Boolean	0 (No)	1 (Yes)	1 (Yes)	1	
Analog Inputs (Deadbands)						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step**	**Unit**
Deadband AI#0	Float	0 %	100 %	100 %	0.0001 %	
Deadband AI#1	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#2	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#3	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#4	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#5	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#6	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#7	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#8	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#9	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#10	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#11	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#12	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#13	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#14	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#15	Float	0 %	100 %	100 %	0. 0001 %	

Counter Inputs (CounterDeadbands)						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step**	**Unit**
Deadband Cont.I#0	Integer	1	32767	1	1	
Deadband Cont.I#1	Integer	1	32767	1	1	
Deadband Cont.I#2	Integer	1	32767	1	1	
Deadband Cont.I#3	Integer	1	32767	1	1	
Deadband Cont.I#4	Integer	1	32767	1	1	
Deadband Cont.I#5	Integer	1	32767	1	1	
Deadband Cont.I#6	Integer	1	32767	1	1	
Deadband Cont.I#7	Integer	1	32767	1	1	
Deadband Cont.I#8	Integer	1	32767	1	1	
Deadband Cont.I#9	Integer	1	32767	1	1	
Deadband Cont.I#10	Integer	1	32767	1	1	
Deadband Cont.I#11	Integer	1	32767	1	1	
Deadband Cont.I#12	Integer	1	32767	1	1	
Deadband Cont.I#13	Integer	1	32767	1	1	
Deadband Cont.I#14	Integer	1	32767	1	1	
Deadband Cont.I#15	Integer	1	32767	1	1	
Deadband Cont.I#16	Integer	1	32767	1	1	
Deadband Cont.I#17	Integer	1	32767	1	1	
Deadband Cont.I#18	Integer	1	32767	1	1	
Deadband Cont.I#19	Integer	1	32767	1	1	

DNP Port 1 Configuration						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step/ Select**	**Unit**
Protocol Select	**Uinteger**	**Procome Dnp3 Modbus**	**Procome Dnp3 Modbus**	**Procome**	**Procome Dnp3 Modbus**	
Baud rate	**Integer**	**300**	**38400**	**38400**	**300 600 1200 2400 4800 9600 19200 38400**	**baud**
Stop Bits	**Integer**	**1**	**2**	**1**	**1**	
Parity	**Integer**	**None Odd Even**	**None Odd Even**	**None**	**None Odd Even**	
Rx Time btw. Char	**Float**	**1**	**60000**	**0.5**	**40**	**msec.**
Comms Fail Ind. Time	**Float**	**0**	**600**	**0.1**	**60**	**s**

Advanced Settings						
Flow control						
CTS Flow	Bool	No Yes	No Yes	No	No Yes	
DSR Flow	Bool	No Yes	No Yes	No	No Yes	
DSR Sensitive	Bool	No Yes	No Yes	No	No Yes	
DTR Control	Integer	Inactive Active Rec. Req.	Inactive Active Rec. Req.	Inactive	Inactive Active Rec. Req.	
RTS Control	Integer	Inactive Active Rec. Req. Sen. Req.	Inactive Active Rec. Req. Sen. Req.	Inactive	Inactive Active Rec. Req. Sen. Req.	
Times						
Tx Time Factor	Float	0	100	1	0.5	
Tx Timeout Const	Uinteger	0	60000	0	1	
Message modification						
Number of Zeros	Integer	0	255	0	1	
collision						
Collision Type	Integer	NO ECHO DCD	NO ECHO DCD	NO	NO ECHO DCD	
Max Retries	Integer	0	3	0	1	
Min Retry Time	Uinteger	0	60000	0	1	msec.
Max Retry Time	Uinteger	0	60000	0	1	msec.

DNP Port 2 and 3 Configuration

Setting Name	Type	Minimum Value	Maximum Value	Default Value	Step/ Select	Unit
Protocol Select	Uinteger	Procome Dnp3 Modbus	Procome Dnp3 Modbus	Procome	Procome Dnp3 Modbus	
Baud rate	Integer	300	38400	38400	300 600 1200 2400 4800 9600 19200 38400	baud
Stop Bits	Integer	1	2	1	1	
Parity	Integer	None Odd Even	None Odd Even	None	None Odd Even	
Rx Time btw. Char	Float	1	60000	0.5	40	msec.
Comms Fail Ind. Time	Float	0	600	0.1	60	s

Advanced Settings						
Operating Mode	Integer	RS-232 RS-485	RS-232 RS-485	RS-232	RS-232 RS-485	
Times						
Tx Time Factor	Float	0	100	1	0.5	
Tx Timeout Const	Uinteger	0	60000	0	1	
Wait N Bytes 485	Integer	0	4	0	1	
Message modification						
Number of Zeros	Integer	0	255	0	1	
collision						
Collision Type	Integer	NO ECHO	NO ECHO	NO	NO ECHO	
Max Retries	Integer	0	3	0	1	
Min Retry Time	Uinteger	0	60000	0	1	msec.
Max Retry Time	Uinteger	0	60000	0	1	msec.

✓ **All settings remain unchanged after a power loss.** F4

DNP Protocol Configuration

- **Relay Number (RTU Address):**
  Remote Terminal Unit Address. Addresses 0xFFF0 to 0xFFFF are reserved as *Broadcast Addresses*.
- **T Confirm Timeout (N7 Confirm Timeout) :**
  Timeout while waiting for Application Layer Confirmation. It applies to Unsolicited messages and Class 1 and Class 2 responses with event data.
- **Max Retries (N7 Retries) :**
  Number of retries of the Application Layer after timeout while waiting for Confirmation.
- **Enable Unsolicited (Enable Unsolicited Reporting) :**
  Enables or disables Unsolicited reporting.
- **Enable Unsol. after Restart :**
  Enables or disables Unsolicited after Restart (for compatibility with terminals whose revision is before DNP3-1998). It has effect only if Enable Unsolicited after Restart is set.
- **Unsolic. Master No. (MTU Address) :**
  Destination address of the Master device to which the unsolicited responses are to be sent. Addresses 0xFFF0 to 0xFFFF are reserved as *Broadcast Addresses*. It is useful only when Unsolicited Reporting is enabled.
- **Unsol. Grouping Time (Unsolicited Delay Reporting) :**
  Delay between an event being generated and the subsequent transmission of the unsolicited message, in order to group several events in one message and to save bandwidth.
- **Synchronization Interval**
  Max interval time between two synchronization. If no synchronizing inside interval, indication IIN1-4 (NEED TIME). This setting has no effect if Synchronization Interval is zero.
- **DNP 3.0 Rev.**
  Certification revision **STANDARD ZIV** or **2003** (DNP3-2003 Intelligent Electronic Device (IED) Certification Procedure Subset Level 2 Version 2.3 29-Sept-03)
- **Binary Changes CLASS.**
  Selection to send Binary Changes as CLASS 1 CLASS 2 CLASS 3 or None.
- **Analog Changes CLASS.**
  Selection to send Analog Changes as CLASS 1 CLASS 2 CLASS 3 or None.
- **Counter Changes CLASS.**
  Selection to send Counter Changes as CLASS 1 CLASS 2 CLASS 3 or None.
- **Binary Status .**
  Send Binary with status otherwise without status
- **32 Bits Analog Input .**
  Send Analog All Variations and Analog Change Event Binary Changes with 32 bits otherwise with 16 bits

DNP Port 1 Port 2 and Port 3 Configuration

- Number of Zeros **(Advice_Time) :**
  Number of zeros before the message.
- Max Retries **(N1 Retries) :**
  Number of retries of the Physical Layer after collision detection.
- Min Retry Time **(Fixed_delay) :**
  Minimum time to retry of the Physical Layer after collision detection.
- Max Retry Time **:**
  Maximum time to retry of the Physical Layer after collision detection.
- Collision Type **:**
  Port 1:
  NO
  ECHO based on detection of transmitted data (monitoring all data transmitted on the link).

  Port 2:
  NO
  ECHO based on detection of transmitted data (monitoring all data transmitted on the link.
  DCD (Data Carrier Detect) based on detecting out-of-band carrier.

  If the device prepares to transmit and finds the link busy, it waits until is no longer busy, and then waits a backoff_time as follows:
  backoff_time = Min Retry Time + random(Max Retry Time - Max Retry Time)
  and transmit. If the device has a collision in transmission the device tries again ,up to a configurable number of retries (Max Retries) if has news collision.

- Wait N Bytes 485**:**
  Number of wait bytes between Reception and transmission Use Port 2 Operate Mode RS-485 .

DNP V3.00 Profile for Ethernet

DEVICE PROFILE DOCUMENT
This document must be accompanied by: **Implementation Table** and **Point List**.

Vendor Name: **ZIV Aplicaciones y Tecnología S.A.**

Device Name: **DLX**

Highest DNP Level Supported:	Device Function:
For Requests 2 For Responses 2	☐ Master ☒ Slave

Notable objects, functions, and/or qualifiers supported in addition to the Highest DNP Levels Supported (the complete list is described in the attached table):

1) Supports Enable/Disable Unsolicited Responses (FC=20 and 21), for classes 1 and 2.
2) Supports Write operations (FC=2) on Time and Date objects.
3) Supports Delay measurement Fine (FC=23).
4) Supports Warm Start command (FC=14).
5) Supports **Unsolicited after Restart (for compatibility with terminals whose revision is before DNP3-1998)**
6) Supports selection of DNP3 Revision.
7) Supports indication of no **synchronization in time.**
8) Supports simultaneous communications with two different Master devices
9) Supports assign event Class for Binary, Analog and Counter events:
   Class 1 , Class 2, Class 3, None
10) Supports respond to Multiple Read Request with multiple object types in the same Application Fragment .

Maximum Data Link Frame Size (octets):	Maximum Application Fragment Size (octets):
Transmitted _____292______ Received _____292______	Transmitted _2048__ (if >2048, must be configurable) Received___249__(must be <= 249)

Maximum Data Link Re-tries:	Maximum Application Layer Re-tries:
☒ None ☐ Fixed at ____________________ ☐ Configurable, range ___ to _____	☐ None ☒ Configurable, range __0__ to __3__ (Fixed is not permitted)

Requires Data Link Layer Confirmation:

☒ Never
☐ Always
☐ Sometimes. If 'Sometimes', when?
____
☐ Configurable. If 'Configurable', how?

Requires Application Layer Confirmation:

- ☐ Never
- ☐ Always (not recommended)
- ☒ When reporting Event Data (Slave devices only) For unsolicited, Class 1 Class 2 and Class 2 responses that contain Event Data. (If there is no Event Data reported into a Class 1 2 or 3 response, Application Layer Confirmation is not requested)
- ☐ When sending multi-fragment responses (Slave devices only)
- ☐ Sometimes. If 'Sometimes', when?
- ☐ Configurable. If 'Configurable', how?

Timeouts while waiting for:

Data Link Confirm	☒ None	☐ Fixed at ____	☐ Variable	☐ Configurable
Complete Appl. Fragment	☒ None	☐ Fixed at ____	☐ Variable	☐ Configurable
Application Confirm	☐ None	☐ Fixed at ____	☐ Variable	☒ Configurable
Complete Appl. Response	☒ None	☐ Fixed at ____	☐ Variable	☐ Configurable

Others ______________________________

Attach explanation if 'Variable' or 'Configurable' was checked for any timeout

Application Confirm timeout setting (***MMI***): Range 50 ms. 65.535 ms.

Sends/Executes Control Operations:

- Maximum number of CROB (obj. 12, var. 1) objects supported in a single message __1
- Maximum number of Analog Output (obj. 41, any var.) supported in a single message__0

☐ Pattern Control Block and Pattern Mask (obj. 12, var. 2 and 3 respectively) supported.

☐ CROB (obj. 12) and Analog Output (obj. 41) permitted together in a single message.

WRITE Binary Outputs	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
SELECT (3) / OPERATE (4)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE (5)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE - NO ACK (6)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable

Count > 1	☐ Never	☐ Always	☒ Sometimes	☐ Configurable
Pulse On	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Pulse Off	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Latch On	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Latch Off	☐ Never	☒ Always	☐ Sometimes	☐ Configurable

Queue	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
Clear Queue	☒ Never	☐ Always	☐ Sometimes	☐ Configurable

Attach explanation:

- All points support the same Function Codes: (3) Select, (4) Operate, (5) Direct Operate and (6) Direct Operate - No ACK.
- Maximum Select/Operate Delay Time: 60 seconds.
- Count can be >1 only for PULSE ON and PULSE OFF

FILL OUT THE FOLLOWING ITEMS FOR SLAVE DEVICES ONLY:	
Reports Binary Input Change Events when no specific variation requested: ☐ Never ☒ Only time-tagged ☐ Only non-time-tagged ☐ Configurable to send both, one or the other (attach explanation)	Reports time-tagged Binary Input Change Events when no specific variation requested: ☐ Never ☒ Binary Input Change With Time ☐ Binary Input Change With Relative Time ☐ Configurable (attach explanation)
Sends Unsolicited Responses: ☐ Never ☒ Configurable (See Note D) ☒ Only certain objects (Class 1 2 and 3) ☐ Sometimes (attach explanation) ☒ ENABLE/DISABLE UNSOLICITED Function codes supported	Sends Static Data in Unsolicited Responses: ☒ Never ☐ When Device Restarts ☐ When Status Flags Change No other options are permitted.
Default Counter Object/Variation: ☐ No Counters Reported ☐ Configurable (attach explanation) ☒ Default Object _20,21____ Default Variation ______1_____ ☐ Point-by-point list attached	Counters Roll Over at: ☐ No Counters Reported ☐ Configurable (attach explanation) ☐ 16 Bits ☐ 32 Bits ☒ Other Value ____31 Bits____ ☐ Point-by-point list attached
Sends Multi-Fragment Responses: ☒ Yes ☐ No	

QUICK REFERENCE FOR DNP3.0 LEVEL 2 FUNCTION CODES & QUALIFIERS		
Function Codes	7 6 5 4 3 2 1 0 [ ] Index Size | Qualifier Code	
1 Read 2 Write 3 Select 4 Operate 5 Direct Operate 9 Direct Operate-No ACK 10 Immediate Freeze 11 Immediate Freeze no ACK 13 Cold Start 14 Warm Start 20 Enable Unsol. Messages 21 Disable Unsol. Messages 23 Delay Measurement 24 Record Current Time 129 Response 130 Unsolicited Message	**Index Size** 0- No Index, Packed 1- 1 byte Index 2- 2 byte Index 3- 4 byte Index 4- 1 byte Object Size 5- 2 byte Object Size 6- 4 byte Object Size	**Qualifier Code** 0- 8-Bit Start and Stop Indices 1- 16-Bit Start and Stop Indices 2- 32-Bit Start and Stop Indices 3- 8-Bit Absolute address Ident. 4- 16-Bit Absolute address Ident. 5- 32-Bit Absolute address Ident. 6- No Range Field (all) 7- 8-Bit Quantity 8- 16-Bit Quantity 9- 32-Bit Quantity 11-(0xB) Variable array

IMPLEMENTATION TABLE

OBJECT			REQUEST (DLX parse)		RESPONSE (DLX respond)		
Obj	**Var**	**Description**	**Func Codes (dec)**	**Qual Codes (hex)**	**Func Codes (dec)**	**Qual Codes (hex)**	**Notes**
1	0	Binary Input – All variations	1	0,1,6,7,8			Assigned to Class 0.
1	1	Binary Input	1	0,1,6,7,8	129	0,1	
2	0	Binary Input with Status	1	0,1,6,7,8	129	0,1	
2	0	Binary Input Change – All variations	1	6,7,8			
2	2	Binary Input Change with Time	1	6,7,8	129,130	17,,28	Assign to Event Class
12	1	Control Relay Output Block	3,4,5,6	17,28	129	17,28	Echo of request
20	0	Binary Counter – All variations	1	0,1,6,7,8			Assigned to Class 0.
20	1	32 Bits Binary Counter			129	0,1	
21	0	Frozen Counter – All variations	1	0,1,6,7,8			
21	1	32 Bits Frozen Counter			129	0,1	
22	0	Counter Change Event – All variations	1	6,7,8			
22	5	32 Bits Counter Change Event With Time			129,130	17,,28	Assign to Event Class
30	0	Analog Input – All variations	1	0,1,6,7,8			Assigned to Class 0.
30	1	32-Bit Analog Input	1	0,1,6,7,8	129	1	
30	2	16-Bit Analog Input	1	0,1,6,7,8	129	1	
32	0	Analog Change Event – All variations	1	6,7,8			
32	3	32-Bit Analog Change Event with Time	1	6,7,8	129,130	28	Assign to Event Class
32	4	16-Bit Analog Change Event with Time	1	6,7,8	129,130	28	Assign to Event Class
50	1	Time and Date	2	7 count=1	129		C
50	3	Time and Date at Last Recorded Time	2	7 count=1	129		C
52	2	Time Delay Fine	23		129	1	F,G

OBJECT			REQUEST (DLX parse)		RESPONSE (DLX respond)		
Obj	Var	Description	Func Codes (dec)	Qual Codes (hex)	Func Codes (dec)	Qual Codes (hex)	Notes
60	1	Class 0 Data	1	6	129	1	
60	2	Class 1 Data	1 20,21	6,7,8 6	129,130	28	D
60	3	Class 2 Data	1 20,21	6,7,8 6	129,130	28	D
60	4	Class 3 Data	1 20,21	6,7,8 6	129,130	28	D
80	1	Internal Indications	2	0 index=7			E
--	--	No Object (Cold Start)	13				F
--	--	No Object (Warm Start)	14				F
--	--	No Object (Delay Measurement)	23				G

NOTES

C: Device supports write operations on Time and Date objects. Time Synchronization-Required Internal Indication bit (IIN1-4) will be cleared on the response.

D: The device can be configured to send or not, unsolicited responses depending on a configuration option by means of ***MMI*** (Man-Machine Interface or front-panel user interface ***ZIVercomPlus***). Then, the Master can Enable or Disable Unsolicited messages (for Classes 1, 2 and 3) by means of requests (FC 20 and 21).
If the unsolicited response mode is configured "on", then upon device restart, the device will transmit an initial Null unsolicited response, requesting an application layer confirmation. While waiting for that application layer confirmation, the device will respond to all function requests, including READ requests.

E: Restart Internal Indication bit (IIN1-7) can be cleared explicitly by the master.

F: The outstation, upon receiving a ***Cold or Warm Start*** request, will respond sending a Time Delay Fine object message (which specifies a time interval until the outstation will be ready for further communications), restarting the DNP process, clearing events stored in its local buffers and setting IIN1-7 bit (Device Restart).

G: Device supports Delay Measurement requests (FC = 23). It responds with the Time Delay Fine object (52-2). This object states the number of milliseconds elapsed between Outstation receiving the first bit of the first byte of the request and the time of transmission of the first bit of the first byte of the response.

DEVICE SPECIFIC FEATURES

- Internal Indication IIN1-6 (Device trouble): **Set to indicate a change in the current DNP configuration in the outstation. Cleared in the next response. Used to let the master station know that DNP settings have changed at the outstation. Note that some erroneous configurations could make impossible to communicate this condition to a master station.**

  This document also states the DNP3.0 settings currently available in the device. If the user changes whatever of these settings, it will set the *Device Trouble Internal Indication* bit on the next response sent.
- Event buffers**: device can hold as much as 128** Binary Input Changes**,** 64 Analog Input Changes and 64 Counter Input Change**. If these limits are reached the device will set the *Event Buffers Overflow Internal Indication* bit on the next response sent. It will be cleared when the master reads the changes, making room for new ones.**
- Configuration ➔ Operation Enable **menu: the device can enable or disable** permissions **for the operations over al Control Relay Output Block. In case permissions are configured off (disabled) the response to a command (issued as Control Relay Output Block) will have the Status code NOT_AUTHORIZED. In case the equipment is** blocked **the commands allowed are the configured when permitted. While blocked, the relay will accept commands over the configured signal. If the equipment is in** operation inhibited state**, the response to all commands over the configured signal will have the Status code NOT_AUTHORIZED.**
- **Customers can configure Inputs/Outputs to suit their needs, by means of** *ZIVercomPlus®* **software.**

POINT LIST

BINARY INPUT (OBJECT 1) -> Assigned to Class 0. BINARY INPUT CHANGE (OBJECT 2) -> Assign to Class.		
Index	**Description**	
0	***Configure by ZIVercomPlus® 2048 points***	
1	***Configure by ZIVercomPlus® 2048 points***	
2	***Configure by ZIVercomPlus® 2048 points***	
3	***Configure by ZIVercomPlus® 2048 points***	
4	***Configure by ZIVercomPlus® 2048 points***	
5	***Configure by ZIVercomPlus® 2048 points***	
6	***Configure by ZIVercomPlus® 2048 points***	
7	***Configure by ZIVercomPlus® 2048 points***	
8	***Configure by ZIVercomPlus® 2048 points***	
9	***Configure by ZIVercomPlus® 2048 points***	
10	***Configure by ZIVercomPlus® 2048 points***	
11	***Configure by ZIVercomPlus® 2048 points***	
12	***Configure by ZIVercomPlus® 2048 points***	
13	***Configure by ZIVercomPlus® 2048 points***	
14	***Configure by ZIVercomPlus® 2048 points***	
15	***Configure by ZIVercomPlus® 2048 points***	
16	***Configure by ZIVercomPlus® 2048 points***	
17	***Configure by ZIVercomPlus® 2048 points***	
...	***Configure by ZIVercomPlus® 2048 points***	
253	***Configure by ZIVercomPlus® 2048 points***	
254	***Configure by ZIVercomPlus® 2048 points***	
255	***Configure by ZIVercomPlus® 2048 points***	

CONTROL RELAY OUTPUT BLOCK (OBJECT 12)		
Index	**Description**	
0	***Configure by ZIVercomPlus® 256 points***	
1	***Configure by ZIVercomPlus® 256 points***	
2	***Configure by ZIVercomPlus® 256 points***	
3	***Configure by ZIVercomPlus® 256 points***	
4	***Configure by ZIVercomPlus® 256 points***	
5	***Configure by ZIVercomPlus® 256 points***	
6	***Configure by ZIVercomPlus® 256 points***	
7	***Configure by ZIVercomPlus® 256 points***	
8	***Configure by ZIVercomPlus® 256 points***	
9	***Configure by ZIVercomPlus® 256 points***	
10	***Configure by ZIVercomPlus® 256 points***	
11	***Configure by ZIVercomPlus® 256 points***	
12	***Configure by ZIVercomPlus® 256 points***	
13	***Configure by ZIVercomPlus® 256 points***	

CONTROL RELAY OUTPUT BLOCK (OBJECT 12)		
Index	**Description**	
14	*Configure by ZIVercomPlus®* 256 points	
15	*Configure by ZIVercomPlus®* 256 points	
16	*Configure by ZIVercomPlus®* 256 points	
17	*Configure by ZIVercomPlus®* 256 points	
...	*Configure by ZIVercomPlus®* 256 points	
253	*Configure by ZIVercomPlus®* 256 points	
254	*Configure by ZIVercomPlus®* 256 points	
255	*Configure by ZIVercomPlus®* 256 points	

ANALOG INPUT (OBJECT 30) -> Assigned to Class 0. ANALOG INPUT CHANGE (OBJECT 32) -> Assign to Class		
Index	**Description**	**Deadband**
0	*Configure by ZIVercomPlus®* 256 points	Deadband_1.
1	*Configure by ZIVercomPlus®* 256 points	Deadband_2.
2	*Configure by ZIVercomPlus®* 256 points	Deadband_3.
3	*Configure by ZIVercomPlus®* 256 points	Deadband_4.
4	*Configure by ZIVercomPlus®* 256 points	Deadband_5.
5	*Configure by ZIVercomPlus®* 256 points	Deadband_6.
6	*Configure by ZIVercomPlus®* 256 points	Deadband_7.
7	*Configure by ZIVercomPlus®* 256 points	Deadband_8.
8	*Configure by ZIVercomPlus®* 256 points	Deadband_9.
9	*Configure by ZIVercomPlus®* 256 points	Deadband_10.
10	*Configure by ZIVercomPlus®* 256 points	Deadband_11.
11	*Configure by ZIVercomPlus®* 256 points	Deadband_12.
12	*Configure by ZIVercomPlus®* 256 points	Deadband_13.
13	*Configure by ZIVercomPlus®* 256 points	Deadband_14.
14	*Configure by ZIVercomPlus®* 256 points	Deadband_15.
15	*Configure by ZIVercomPlus®* 256 points	Deadband_16.

Additional assign with ***ZIVercomPlus***⑧:

Index	Description
16	***Configure by ZIVercomPlus*⑧ 256 *points***
17	***Configure by ZIVercomPlus*⑧ 256 *points***
18	***Configure by ZIVercomPlus*⑧ 256 *points***
19	***Configure by ZIVercomPlus*⑧ 256 *points***
20	***Configure by ZIVercomPlus*⑧ 256 *points***
21	***Configure by ZIVercomPlus*⑧ 256 *points***
22	***Configure by ZIVercomPlus*⑧ 256 *points***
23	***Configure by ZIVercomPlus*⑧ 256 *points***
24	***Configure by ZIVercomPlus*⑧ 256 *points***
25	***Configure by ZIVercomPlus*⑧ 256 *points***
26	***Configure by ZIVercomPlus*⑧ 256 *points***
27	***Configure by ZIVercomPlus*⑧ 256 *points***
....	***Configure by ZIVercomPlus*⑧ 256 *points***
62	***Configure by ZIVercomPlus*⑧ 256 *points***
63	***Configure by ZIVercomPlus*⑧ 256 *points***

The full scale ranges are adjustable and user's magnitudes can be created. It's possible to choose between primary and secondary values, considering CT and PT ratios. Typical ranges in secondary values are:

Description	Full Scale Range		
	Engineering units	Counts	
Currents (Phases, sequences, harmonics)	0 to 1,2 x InPHASE A	0 to 32767	**Deadband**
Currents (Ground, polarizing)	0 to 1,2 x InGROUND A	0 to 32767	**Deadband**
Currents (Ground sensitive, isolated neutral)	0 to 1,2 A	0 to 32767	**Deadband**
Voltages (Phase to ground, sequences, harmonics)	0 to 1,2 x Vn/√3 V	0 to 32767	**Deadband**
Voltages(Phase to phase, synchronizing)	0 to 1,2 x Vn V	0 to 32767	**Deadband**
Power (Real, reactive, apparent)	0 to 3 x 1,4 x InPHASE x Vn/√3 W	-32768 to 32767	**Deadband**
Power factor	-1 to 1	-32768 to 32767	**Deadband**
Frequency	0 to 1,2 x Rated frequency (50/60 Hz)	0 to 32767	**Deadband**
Thermal value	0 to 200%	0 to 32767	**Deadband**
Distance to Fault - **Percentage of line length:** 100% sends 32767 counts (range from -100% to 100%) - **Distance in kilometers:** with the "line length" sends 32767 counts (range from - "line length" to the "line length" set in km) - **Distance in miles:** with the "line length" sends 32767 counts (range from - "line length" to the "line length" set in miles)		-32768 to 32767	**Deadband**

Communication Measure in Counts

With ***ZIVercomPlus*** program is possible to define the ***Full Scale Range*** that is desired to transmit each magnitude in *counts*. Parameters necessary to configure the Mathematical expression are:

- **Offset:** A number indicating the compensation of de Magnitude.
- **Limit:** it's the Maximum value of magnitude range.
- **Max Communication:** it's a constant that depend of the Number Bits of Analog Input.
  Max Communication=2(Number Bits Analog Input - 1)**
  For 16-Bit Analog Input (Obj. 30 Var. 2) 2**(15) = 32.767 counts
  For 32-Bit Analog Input (Obj. 30 Var. 1) 2**(31) = 2.147.483.647 counts
- **Rated value:** Nominal Value of the magnitude.
- **Nominal Flag:** This *flag* defines if the **limit** is proportional to the **rated value** of the magnitude.
- **TR:** Secondary to Primary Transformation Ratio.

Mathematical expression to describe the ***Full Scale Range*** is:

- When **Nominal Flag** is actived,

$$MeasureCom = TR \times \frac{Measure - Offset}{RatedValue} \times \frac{MaxComunication}{Limit}$$

- When **Nominal Flag** is NOT actived,

$$MeasureCom = TR \times (Measure - Offset) \times \frac{MaxComunication}{Limit}$$

Communication Measure in Engineering Units

With ***ZIVercomPlus*** program **also** it's possible to transmit each magnitude in Engineering Units. Parameters necessary to configure the Mathematical expression are:

- **Offset:** A number indicating the compensation of de magnitude.
- **Limit:** it's the Maximum value of magnitude range.
- **Rated value:** Nominal Value of the magnitude.
- **Nominal Flag:** this *flag* defines if the **limit** is proportional to the **rated value** of the magnitude or not. The rated value of the new magnitudes defined by the user is a setting, while for the pre-defined magnitudes is a fix value.
- **TR:** Secondary to Primary Transformation Ratio.
- **Scaling Factor:** Multiply Factor of magnitude.

Mathematical expression to obtain **Measure in Engineering Units** is:

- When **Nominal Flag** is actived,

$$MeasureCom = TR \times \frac{Measure - Offset}{RatedValue} \times ScalingFactor$$

- When **Nominal Flag** is NOT actived,

$$MeasureCom = TR \times (Measure - Offset) \times ScalingFactor$$

DeadBands

- Deadband is an area of a magnitude range or band where no generate magnitude change (the magnitude is dead). Meaning that no generation of Analogical Change Events if difference with value of generation of previous change is not equal or greater that DeadBand calculated. There is an independent setting for each 16 Measures with change.
- A Deadband is calculated as a percentage defined in DeadBand Setting over value of **parameter Limit**.
- The Deadband can be adjusted to the device by means of ***MMI*** (Man-Machine Interface or front-panel user interface *ZIVercomPlus*), between 0.0000% and 100.00%, in steps of 0.0001%. Default value is 100.00%, meaning that generation of Analog Change Events is **DISABLED** for that input. There is an independent setting for each Magnitude with change.

BINARY COUNTER (OBJECT 20) -> Assigned to Class 0. **FROZEN COUNTER (OBJECT 21)** **32 BIT COUNTER CHANGE EVENT (OBJECT 22) -> Assign to Class**		
Index	Description	Deadband
0	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_1.**
1	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_2.**
2	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_3.**
3	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_4.**
4	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_5.**
5	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_6**
6	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_7.**
7	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_8.**
8	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_9.**
9	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_10.**
10	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_11.**
11	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_12.**
12	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_13.**
13	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_14.**
14	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_15.**
15	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_16.**
16	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_17.**
17	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_18.**
18	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_19.**
19	***Configure by ZIVercomPlus®* 256 points**	**CounterDeadBand_20.**

CounterDeadBands

- CounterDeadband is an area of a counter magnitude range or band, where no generate counter magnitude change (the communication counter magnitude is dead).Meaning that no generation of Counter Change Events if difference with value of generation of previous change is not equal or greater that CounterDeadBand setting. There is an independent setting for each Counter.

- The CounterDeadband can be adjusted to the device by means of ***MMI*** (Man-Machine Interface or front-panel user interface *ZIVercomPlus*), between 1 and 32767, in steps of 1, default value is 1.

DNP3 PROTOCOL SETTINGS

DNP3 Protocol Settings						
DNP Protocol Configuration						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step/ Select**	**Unit**
Relay Number	Integer	0	65519	1	1	
T Confirm Timeout	Integer	1000	65535	1000	1	msec.
Max Retries	Integer	0	65535	0	1	
Enable Unsolicited.	Boolean	0 (No)	1 (Yes)	0 (No)	1	
Enable Unsol. after Restart	Boolean	0 (No)	1 (Yes)	0 (No)	1	
Unsolic. Master No.	Integer	0	65519	1	1	
Unsol. Grouping Time	Integer	100	65535	1000	1	msec.
Synchronization Interval	Integer	0	120	0	1	min.
DNP 3.0 Rev.	Integer	2003 ST.ZIV	2003 ST.ZIV	2003	2003 ST.ZIV	
Binary Changes CLASS	Integer	None Class 1 Class 2 Class 3	None Class 1 Class 2 Class 3	Class 1	None Class 1 Class 2 Class 3	
Analog Changes CLASS	Integer	None Class 1 Class 2 Class 3	None Class 1 Class 2 Class 3	Class 2	None Class 1 Class 2 Class 3	
Counter Changes CLASS	Integer	None Class 1 Class 2 Class 3	None Class 1 Class 2 Class 3	Class 3	None Class 1 Class 2 Class 3	
Binary Status Change	Boolean	0 (No)	1 (Yes)	1 (Yes)	1	
32 Bits Analog Input	Boolean	0 (No)	1 (Yes)	1 (Yes)	1	
Analog Inputs (Deadbands)						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step**	**Unit**
Deadband AI#0	Float	0 %	100 %	100 %	0.0001 %	
Deadband AI#1	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#2	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#3	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#4	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#5	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#6	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#7	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#8	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#9	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#10	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#11	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#12	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#13	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#14	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#15	Float	0 %	100 %	100 %	0. 0001 %	

Counter Inputs (CounterDeadbands)						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step**	**Unit**
Deadband Cont.I#0	Integer	1	32767	1	1	
Deadband Cont.I#1	Integer	1	32767	1	1	
Deadband Cont.I#2	Integer	1	32767	1	1	
Deadband Cont.I#3	Integer	1	32767	1	1	
Deadband Cont.I#4	Integer	1	32767	1	1	
Deadband Cont.I#5	Integer	1	32767	1	1	
Deadband Cont.I#6	Integer	1	32767	1	1	
Deadband Cont.I#7	Integer	1	32767	1	1	
Deadband Cont.I#8	Integer	1	32767	1	1	
Deadband Cont.I#9	Integer	1	32767	1	1	
Deadband Cont.I#10	Integer	1	32767	1	1	
Deadband Cont.I#11	Integer	1	32767	1	1	
Deadband Cont.I#12	Integer	1	32767	1	1	
Deadband Cont.I#13	Integer	1	32767	1	1	
Deadband Cont.I#14	Integer	1	32767	1	1	
Deadband Cont.I#15	Integer	1	32767	1	1	
Deadband Cont.I#16	Integer	1	32767	1	1	
Deadband Cont.I#17	Integer	1	32767	1	1	
Deadband Cont.I#18	Integer	1	32767	1	1	
Deadband Cont.I#19	Integer	1	32767	1	1	
DNP Port 1 Port 2 and 3 DNP 3 Profile II Ethernet Configuration						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step**	**Unit**
Protocol Select	**Uinteger**	**Procome Dnp3 Modbus**	**Procome Dnp3 Modbus**	**Procome**	**Procome Dnp3 Modbus**	
Enable Ethernet Port	**Boolean**	**0 (No)**	**1 (Yes)**	**1 (Yes)**	**1**	
IP Address Port 1	**Byte[4]**	**ddd.ddd.ddd.ddd**	**ddd.ddd.ddd.ddd**	**192.168.1.51**	**1**	
IP Address Port 2	**Byte[4]**	**ddd.ddd.ddd.ddd**	**ddd.ddd.ddd.ddd**	**192.168.1.61**	**1**	
IP Address Port 3	**Byte[4]**	**ddd.ddd.ddd.ddd**	**ddd.ddd.ddd.ddd**	**192.168.1.71**	**1**	
Subnet Mask	**Byte[4]**	**128.0.0.0**	**255.255.255.254**	**255.255.255.0**	**1**	
Port Number	**Uinteger**	**0**	**65535**	**20000**	**1**	
Keepalive Time	**Float**	**0**	**65**	**30**	**60**	**s.**
Rx Time Characters	**Float**	**1**	**60000**	**1**	**0.5**	**ms.**
Comms Fail Timer	**Float**	**0**	**600**	**60**	**0.1**	**s.**

✓ **All settings remain unchanged after a power loss.**

DNP Protocol Configuration

- Relay Number (**RTU Address**):
  Remote Terminal Unit Address. Addresses 0xFFF0 to 0xFFFF are reserved as *Broadcast Addresses*.
- T Confirm Timeout (**N7 Confirm Timeout**) :
  Timeout while waiting for Application Layer Confirmation. It applies to Unsolicited messages and Class 1 and Class 2 responses with event data.
- Max Retries (**N7 Retries**) :
  Number of retries of the Application Layer after timeout while waiting for Confirmation.
- Enable Unsolicited (**Enable Unsolicited Reporting**) :
  Enables or disables Unsolicited reporting.
- Enable Unsol. after Restart :
  Enables or disables Unsolicited after Restart (for compatibility with terminals whose revision is before DNP3-1998). It has effect only if Enable Unsolicited after Restart is set.
- Unsolic. Master No. (**MTU Address**) :
  Destination address of the Master device to which the unsolicited responses are to be sent. Addresses 0xFFF0 to 0xFFFF are reserved as *Broadcast Addresses*. It is useful only when Unsolicited Reporting is enabled.
- Unsol. Grouping Time (**Unsolicited Delay Reporting**) :
  Delay between an event being generated and the subsequent transmission of the unsolicited message, in order to group several events in one message and to save bandwidth.
- Synchronization Interval
  Max interval time between two synchronization. If no synchronizing inside interval, indication IIN1-4 (NEED TIME). This setting has no effect if Synchronization Interval is zero.
- DNP 3.0 Rev.
  Certification revision **STANDARD ZIV** or **2003** (DNP3-2003 Intelligent Electronic Device (IED) Certification Procedure Subset Level 2 Version 2.3 29-Sept-03)
- Binary Changes CLASS.
  Selection to send Binary Changes as CLASS 1 CLASS 2 CLASS 3 or None.
- Analog Changes CLASS.
  Selection to send Analog Changes as CLASS 1 CLASS 2 CLASS 3 or None.
- Counter Changes CLASS.
  Selection to send Counter Changes as CLASS 1 CLASS 2 CLASS 3 or None.
- Binary Status .
  Send Binary with status otherwise without status
- 32 Bits Analog Input .
  Send Analog All Variations and Analog Change Event Binary Changes with 32 bits otherwise with 16 bits

DNP PROFILE II ETHERNET Port 1 Port 2 and Port 3 Configuration

- **Enable Ethernet Port :**
  Enables or disables Ethernet Port.

- **IP Address :**
  Identification Number of Ethernet device.

- **Subnet Mask :**
  Indicate the part of IP Address is the Net Address and the part of IP Address is the Device Number.

- **Port Number :**
  Indicate to Destinatión Device the path to send the recived data.

- **Keepalive Time :**
  Number of second between Keepalive paquets, if zero no send packages Keepalive. These packages allow to Server know if a Client is present in the Net.

- **Rx Time Between Characters :**
  Maximum time between Characters.

- **Comm Fail Timer :**
  Maximum time between Messages without indicate Communication Fail.

C. MODBUS RTU. Documentation. Address Map

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C.1 Preliminary Information

This a reference document for implementing the MODBUS RTU protocol in the **DLX** IED.

This document provides a detailed MODBUS address map (input status, coil status, input registers and force single coil) and their equivalent in the **DLX** relay.

The functions that will be implemented are:

ModBus Function	Meaning
01	Read Coil Status
02	Read Input Status
04	Read Input Registers
05	Force Single Coil

Any other function not among those indicated will be considered illegal and will return exception code 01 (Illegal function).

C.2 Function 01: Read Coil Status

C.2.1 Modbus Address Map for DLX

The MODBUS coil status address map for the **DLX** relay will be:

Address	Description
Configurable through the *ZivercomPlus*®	Any input or output logic signal from the protection modules or generated by the programmable logic.

The content of the addresses is variable (reflection of each relay's configuration). The range of addresses is from 0 to 1023 and they are assigned automatically by the ***ZivercomPlus***® program.

Non-configured addresses will be considered illegal and will return exception code 02 (Illegal Data Address).

C.3 Function 02: Read Input Status

C.3.1 Modbus Address Map for DLX

The MODBUS input status address map for the **DLX** relay will be:

Address	Description
Configurable through the *ZivercomPlus*®	Any input or output logic signal from the protection modules or generated by the programmable logic.

The content of the addresses is variable (reflection of each relay's configuration). The range of addresses is from 0 to 1023 and they are assigned automatically by the ***ZivercomPlus***® program.

Non-configured addresses will be considered illegal and will return exception code 02 (Illegal Data Address).

C.4 Function 03: Read Holding Registers

C.4.1 Modbus Address Map for DLX

The MODBUS read holding registers address map for the **DLX** relay will be:

Address	Description
Configurable through the *ZivercomPlus*®	Any input or output logic signal from the protection modules or generated by the programmable logic whose number of changes is to be measured.

Configurable through the ***ZivercomPlus***®: Counters can be created with any signal configured in the programmable logic or from the protection modules. The default counters are those of the real energies (positive and negative) and the reactive energies (capacitive and inductive).

The metering range of energies in primary values is from 100wh/varh to 6553.5 kWh/kVArh. This is the magnitude transmitted via communications. That is, one (1) count represents 100 wh/varh.

To obtain an energy counter with a higher maximum value, a “user magnitude” must be created using this counter. For example, dividing the value of the counter by 1000 and making the output of the divider the new magnitude yields an energy counter with a range from 100 kWh/kVArh to 6553.5 MWh/Mvarh; that is, one (1) count represents 100 kWh/varh.

The content of the addresses is variable (reflection of each relay's configuration). The range of addresses is from 0 to 255 and they are assigned automatically by the ***ZivercomPlus***® program.

Non-configured addresses will be considered illegal and will return exception code 02 (Illegal Data Address).

C.5 Function 04: Read Input Registers

C.5.1 Modbus Address Map for DLX

The MODBUS read input registers address map for the **DLX** relay will be:

Address	Description
Configurable through the *ZivercomPlus*®	Any magnitude measured or calculated by the protection or generated by the programmable logic. It is possible to select between primary and secondary values, taking into account the corresponding transformation ratios.

All the full scale values of the magnitudes are definable, and these magnitudes can be used to create **user values**. Some typical values are:

- Phase and sequence currents and harmonics: **Rated Value I_{PHASE} + 20**% sends 32767 counts.
- Ground and synchronization currents: **Rated Value I_{GROUND} + 20%** sends 32767 counts.
- Sensitive ground and directional ungrounded neutral currents: **1.2 A** sends 32767 counts.
- Line-to-neutral and sequence voltages and harmonics: **(Rated Value V / √3) + 20%** sends 32767 counts.
- Phase-to-phase and polarization voltages: **Rated Value V + 20%** sends 32767 counts.
- Powers: 3 x 1.4 x Rated value I_{PHASE} x Rated value / √3 sends 32767 counts.
- Power factor: from **-1** to **1** sends from -32767 to 32767 counts.
- Frequency: from **0 Hz** to **1.2 x $\mathbf{Frequency_{RATED}}$** (50Hz / 60Hz) sends 32767 counts.
- Thermal value: **240%** sends 32767 counts.
- Distance to the fault:
  - Percentage value: **±100%** sends ±32767 counts (range from -100% to 100%).
  - Value in kilometers: with the **Length of the Line**, it sends ±32767 counts (range from 0 km to the length of the line set in km. It can also send negative values).
  - Value in miles: with the **Length of the Line**, it sends ±32767 counts (range from 0 km to the length of the line set in miles. It can also send negative values).

With the ***ZivercomPlus***® program, it is possible to define the full-scale value to be used to transmit this magnitude in counts, the unit that all the protocols use. There are three definable parameters that determine the range of distance covered:

- **Offset Value**: the minimum value of the magnitude for which 0 counts are sent.
- **Limit**: the length of the range of the magnitude on which it is interpolated to calculate the number of counts to send. If the offset value is 0, it coincides with the value of the magnitude for which the defined maximum of counts (32767) is sent.
- **Nominal Flag**: this flag allows determining whether the limit set is proportional to the rated value of the magnitude or not. The rated value of the new magnitudes defined by the user in the programmable logic can be configured, while the rest of the existing magnitudes are fixed.

The expression that allows defining this full-scale value is the following:

- -When the Nominal flag is enabled,

$$CommunicationsMeasurement = \frac{Measurement - Offset}{Nominal} \times \frac{32767}{Limit}$$

- -When the Nominal flag is NOT enabled,

$$CommunicationsMeasurement = (Measurement - Offset) \times \frac{32767}{Limit}$$

The content of the addresses is variable (reflection of each relay's configuration). The range of addresses is from 0 to 255 and they are assigned automatically by the ***ZivercomPlus®*** program.

Non-configured addresses will be considered illegal and will return exception code 02 (Illegal Data Address).

C.6 Function 05: Force Single Coil

C.6.1 Modbus Address Map for DLX

The MODBUS force single coil address map of the **DLX** relay will be:

Address	Description
Configurable through the *ZivercomPlus®*	A command can be made on any input from the protection modules and on any signal configured in the programmable logic.

The content of the addresses is variable (reflection of each relay's configuration). The range of addresses is from 0 to 255 and they are assigned automatically by the ***ZivercomPlus®*** program.

Non-configured addresses will be considered illegal and will return exception code 02 (Illegal Data Address).

Any value other than 00H or FFH will be considered illegal and will return exception code 03 (Illegal Data Value).

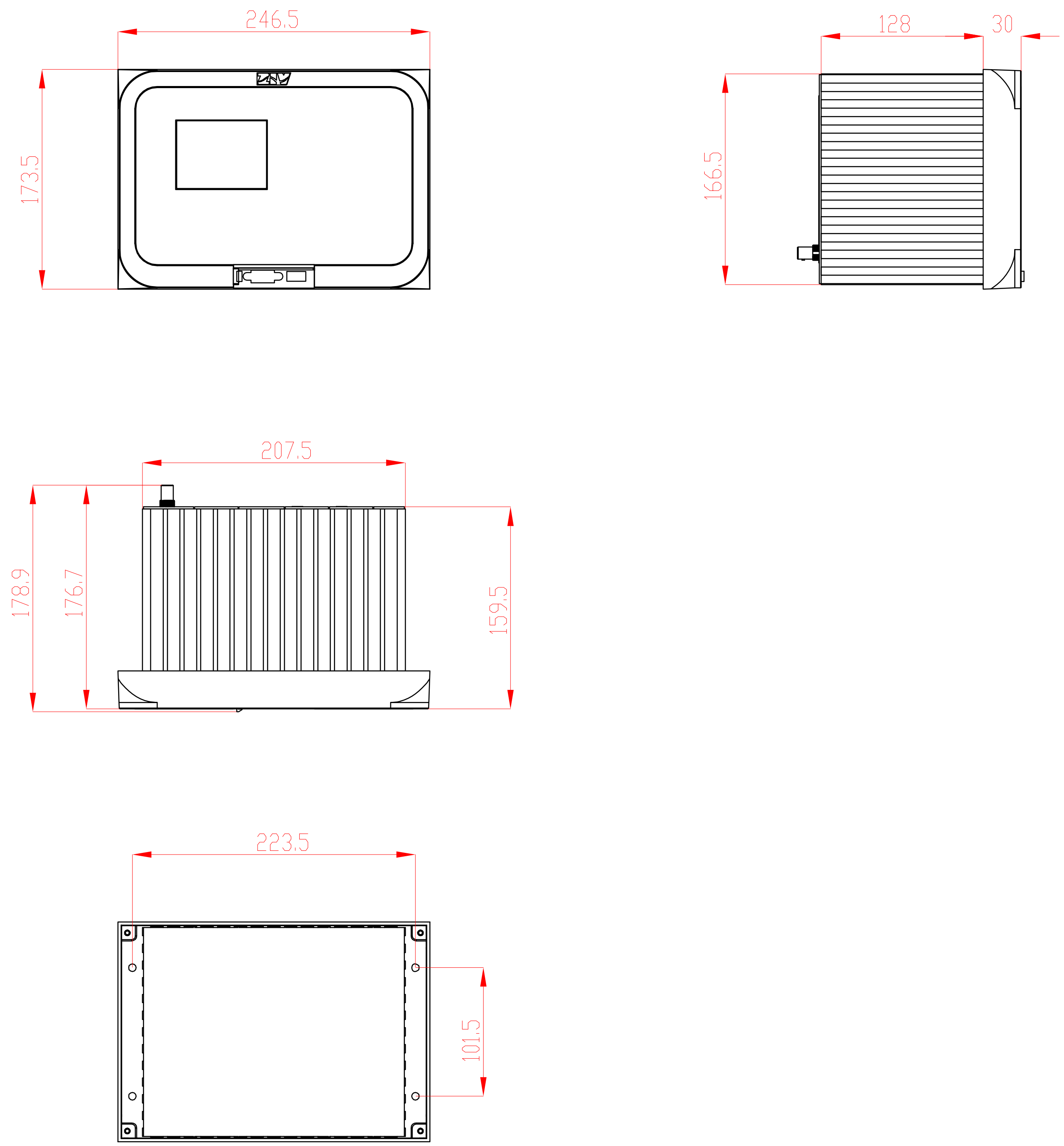
D. Schemes and Drawings

Dimension and Drill Hole Schemes

2DLX (6U x 1/2 19" rack)	>>4BF0102/0001

External Connection Schemes

2DLX-A-***100**	>>3RX0199/0005 (generic)
2DLX-A-***000**	>>3RX0199/0005 (generic)
2DLX-B	>>3RX0199/0008 (generic)



REVISIONES		0	CD0801128	1	CD0901130
2		3		4	
5		6		7	
8		9		10	
11		12		13	
14		15		16	

ZIV Aplicaciones y Tecnologia S.A.

TITULO: DIMENSIONES

PROYECTO: CAJA 2IRX-B(100)

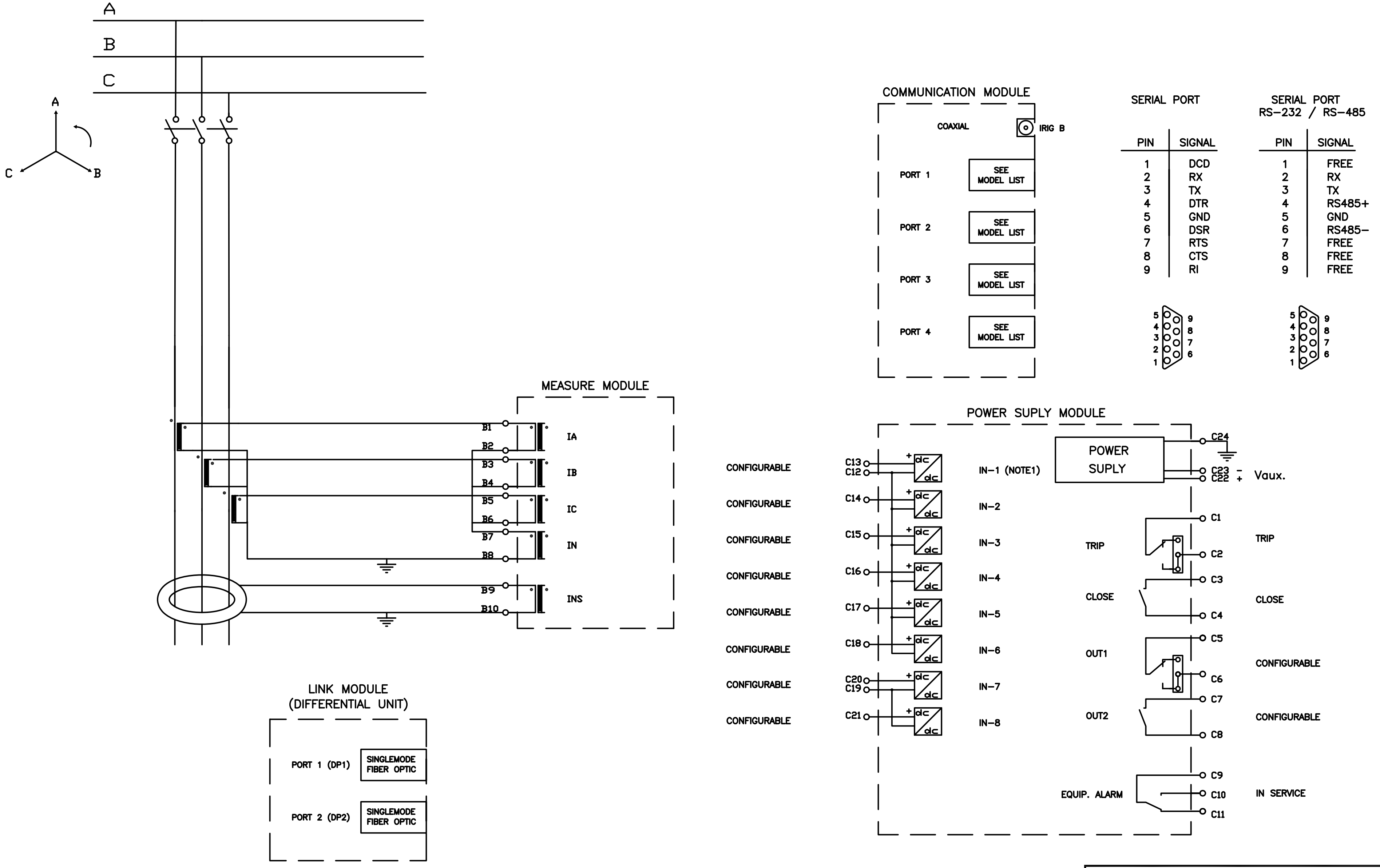
Rev.0
Rev. 1 10/2/09

NUMERO: 4BF0102/0001

	Fecha	Nombre
Dibujado	29/01/08	J.C.S.
Aprobado	29/01/08	P.A.

Hoja: 1

Continua en Hoja:



SERIAL PORT

PIN	SIGNAL
1	DCD
2	RX
3	TX
4	DTR
5	GND
6	DSR
7	RTS
8	CTS
9	RI

SERIAL PORT RS-232 / RS-485

PIN	SIGNAL
1	FREE
2	RX
3	TX
4	RS485+
5	GND
6	RS485-
7	FREE
8	FREE
9	FREE

SERIAL PORT RJ45

PIN	SIGNAL
1	TX+
2	TX-
3	RX+
4	N/C
5	N/C
6	RX-
7	N/C
8	N/C

SERIAL PORT CAN

PIN	SIGNAL
1	H
2	L
3	GND

NOTE 1: TERMINAL C13 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS IN2 OR IN3 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.

REVISIONS	0	CD1102114	1		2		3		4	
5	6		7		8		9		10	
11	12		13		14		15		16	

Z I V Aplicaciones y Tecnologia S.A.

TITLE: EXTERNAL CONNECTIONS 2DLX-A (100)

PROJECT: DLX

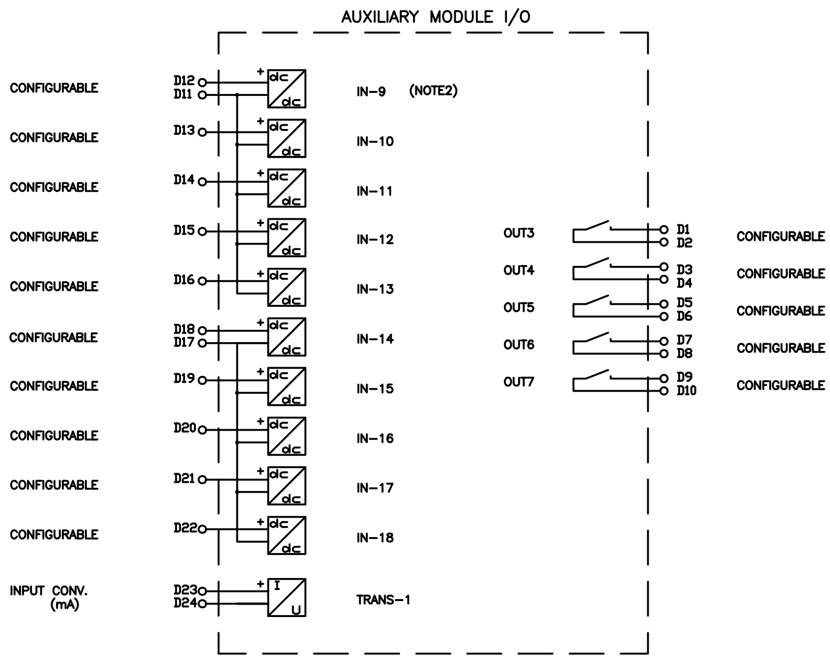
Rev.0

NUMBER: 3RX0199/0005

	Date	Name
Drawn	28/1/11	G.E.
Approved	28/1/11	J.M.Y.

Sheet: 1

Continued on Sheed: 2



NOTE 2: TERMINAL D12 SHOULD BE CONNECTED WHEN ANY OF THE INPUTS IN10, IN11, IN12 OR IN13 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.

REVISIONS	0	CD1102114	1		2		3		4	
5			6		7		8		9		10
11			12		13		14		15		16

Z I V Aplicaciones y Tecnologia S.A.

TITLE: EXTERNAL CONNECTIONS 2DLX-A (100)

PROJECT: DLX

Rev.0

NUMBER: 3RX0199/0005

	Date	Name
Drawn	28/1/11	G.E.
Approved	28/1/11	J.M.Y.

Sheet: 2

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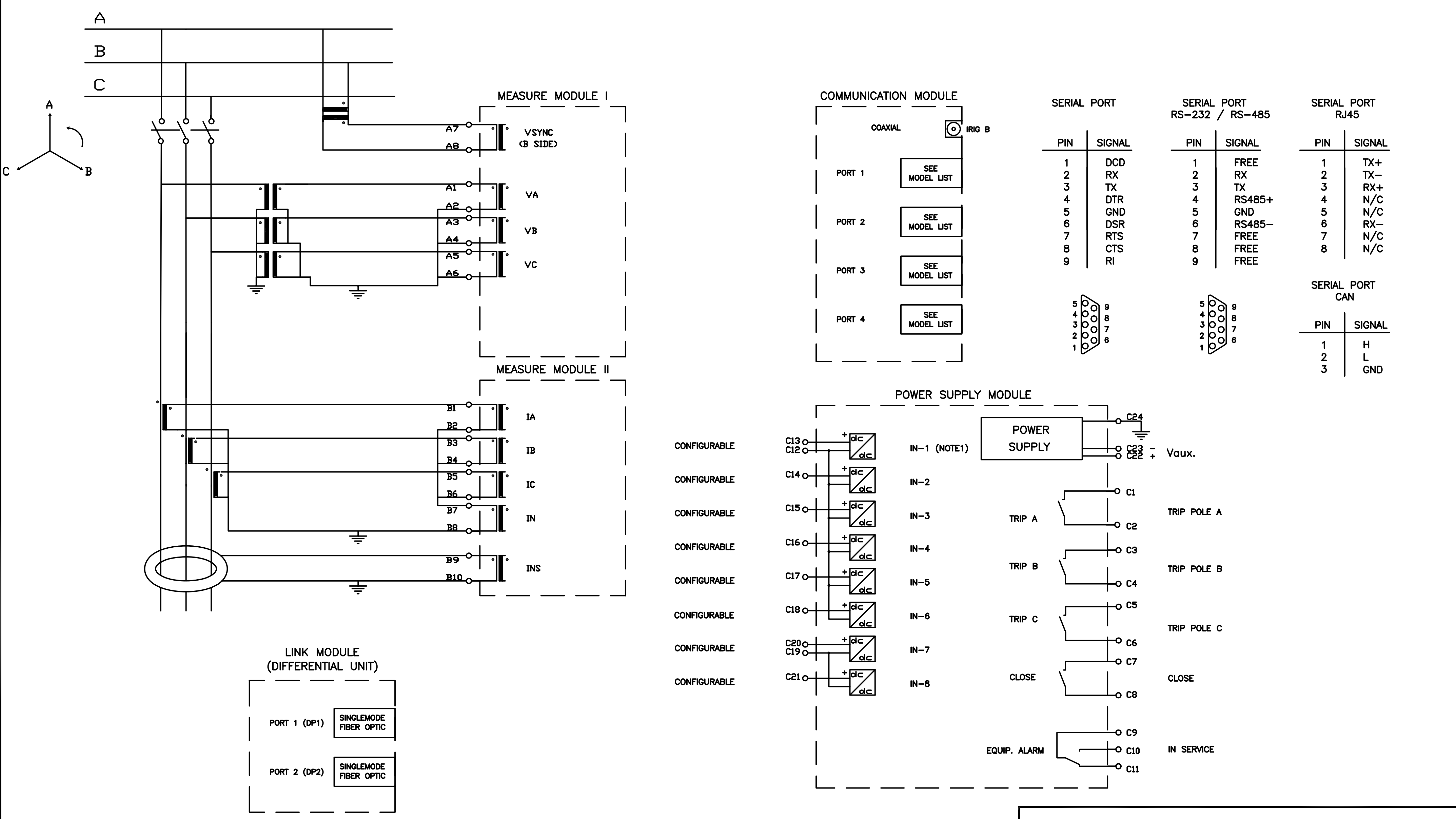

SERIAL PORT

PIN	SIGNAL
1	DCD
2	RX
3	TX
4	DTR
5	GND
6	DSR
7	RTS
8	CTS
9	RI

SERIAL PORT RS-232 / RS-485

PIN	SIGNAL
1	FREE
2	RX
3	TX
4	RS485+
5	GND
6	RS485-
7	FREE
8	FREE
9	FREE

SERIAL PORT RJ45

PIN	SIGNAL
1	TX+
2	TX-
3	RX+
4	N/C
5	N/C
6	RX-
7	N/C
8	N/C

SERIAL PORT CAN

PIN	SIGNAL
1	H
2	L
3	GND

NOTE 1: TERMINAL C13 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS IN2 OR IN3 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.

REVISIONS	0	CD1102114	1		2		3		4	
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11	12		13		14		15		16	

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Rev.0

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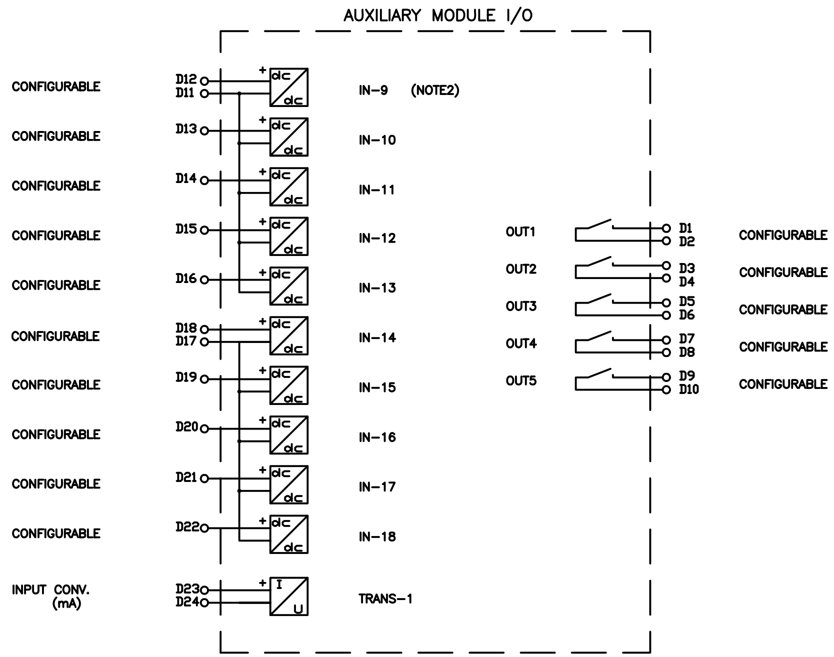

NOTE 2: TERMINAL D12 SHOULD BE CONNECTED WHEN ANY OF THE INPUTS IN10, IN11, IN12 OR IN13 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.

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11	12		13		14		15		16	

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