NEW GENERATION OF DISTRIBUTED ARCHITECTURE PROTECTION AND CONTROL TERMINALS

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During the past years, the electric markets in some developed countries have experienced significant changes. Such changes will continue evolving in the near future, and surely reaching many of the countries that have not yet been affected by this renovating wave.

Privatizing, deregulation, competition, ... such words are gaining strength among the management of electric power companies. Words that are the new key points to generate value in businesses. Businesses that, in the past, operated in safe and regulated markets.

New conditions where old terms, such as consumers, are being substituted by new terms to these markets, such as customers.

Consumers were passive economic entities that played a role as receptors of a service. On the other hand, customers are active economic agents, who purchase a service demanding high quality standards. Standards that are based on the uniqueness of the needs and businesses of such customers.

These changes are the cause of new balancing points:

- Business must be profitable and must offer the quality of service required by customers who have a choice of provider.
- Markets where productivity is the cornerstone; often meaning reducing personnel to get more work done in an improved manner.
- Businesses that must survive in a changing environment by following the market rules. Today's rules are tomorrow's dead letter. These changing conditions not only require forecasting abilities, but rapid adaptability and flexibility to respond to the new conditions.

The survival in the electricity market, shares a common point that already has become true in other markets. This point is well described by the Red Queen in Lewis Carroll "Through the Looking-Glass".

> *"Now,* here*, you see, it takes all the running* you *can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!"*

In these new markets, technology becomes an essential tool to increase business value. Technology boosts the quality of service, which today is defined by highly demanding requirements, increasing productivity levels, without neglecting the ever-changing environment where flexibility is a must.

The role of the manufacturer is to cooperate with power companies by providing state-of-the-art equipment and services, and improving on the traditional high quality levels required in the industry. New features will be added to the conventional ones, such as:

> Flexibility, versatility, focus and adaptability to the customer, ease in commissioning and maintenance, and the ability to evolve in the future.

The new benchmarks will be defined by these characteristics.

DESIGN REQUIREMENTS

The preceding section clearly states the requirements needed in any proposal to electrical utilities today. Such requirements will mark the difference between ordinary vendors and providers of value for the businesses of their customer:

- Flexibility and versatility
- Focus and adaptability to both the customer and the application
- Ease of commissioning and maintenance
- Ability to evolve in the future

Without forgetting what, in many cases, is taken for granted:

- Suitable functionality
- Cost effectiveness

SCOPE

The object of this paper is to introduce a complete line of protection and control IEDs. The line's generic name is the IRX Series, and it has been conceived and designed following the requirements described above.

DISTRIBUTED ARCHITECTURE

Distributed architecture is a concept already applied in many different technical fields, taking a different form in each case. During the last few years, distributed architecture has been successfully introduced in the field of protection and control of power machines and power systems. These applications were limited to the bay level. The IRX Series takes one step ahead, inside the bay itself, dividing the protection and control IED into different units. Each unit has a different function to interface within the system.

Physical and Functional Distribution

After analyzing the data processing and interface functions of a protection and control IED within the system, it is possible to differentiate the following components:

1. Processing Unit (CPU)
2. Human-Machine Interface (HMI)
3. Inputs / Outputs (I/O)

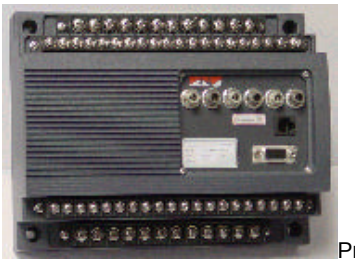
In the IRX Series, the protection and control IED concept is divided in these three different units. Such units are physically independent, yet seamlessly integrated through communications. This approach includes all the functionality of traditional IEDs, while adding new features impossible to attain with conventional compact terminal units.

The **processing unit** houses the intelligence of the system and all the required data processing capacity needed in the application. It also includes, the analog inputs, and the communication ports for local access and interface with the upper levels of the system. A set of contact inputs and auxiliary outputs required for almost every application is also part of this module.

The **human-machine interface** provides all the required features to enable the user access for: control operations, analysis of information, review and modification of settings, etc., either by means of using the keypad and displays, or by accessing with a PC and a software package via a RS232 port.

The **input / output module** has two complementary functions: interface expansion in instances where the capabilities of the processing unit are not sufficient, and easy connection of distant devices.

Figure 1 shows each of the three units described.



Processing Unit

I/O Expansion Module

Human-Machine Interface

Figure 1

Figure 2 shows the application scheme of the different modules to form the protection and control system of a substation bay. The processing unit is able to interface with up to thirty-two (32) I/O modules. Figure 2 includes two (2) I/O modules

The processing unit includes two independent communication ports to interface with the other devices that comprise the system. In both cases a fiber optic network is utilized. A star network configuration (peer-to-peer) is used to connect with the HMI units and a ring configuration is used to include the I/O modules.

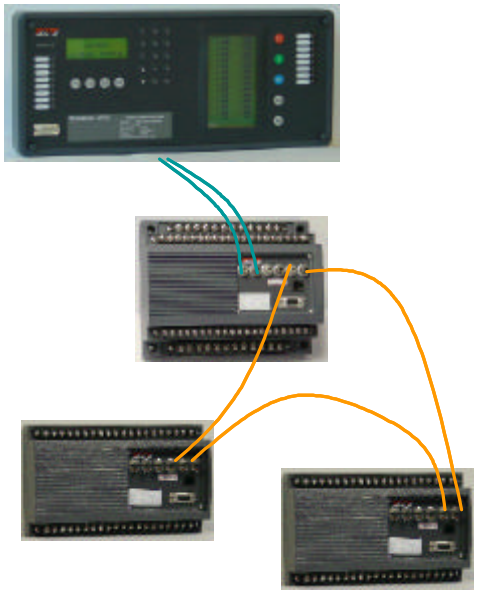


Figure 2

APLICATION NOTES

This innovative architecture allows for the creation of new applications, but the design process is reversed. Devising new applications has been the starting point in the design process. The following paragraphs include some of the capabilities of the system. In many cases the capabilities are the natural result from using independent devices.

Some of these solutions are groundbreaking, where other solutions come from focusing on old problems from a new point of view. To illustrate the first group of solutions, two new approaches to utilize the HMI are described. An example of the second group describes three ways to optimize the usage of the available space.

Shared Human-Machine Interface

An independent HMI provides an affirmative answer to the following question: Is it possible to utilize a single HMI to interface with all the devices on the system or with a selected group of devices?

Figure 3 depicts an application scheme where a single HMI unit is allowed access to a group of processing units. By utilizing the HMI as a shared resource, local access is achieved through a common point and the cost of the system is reduced.

Figure 4 shows another interesting option. In this case, a single processing unit is controlled from two different locations via two different HMIs. Figure 4 also depicts the application of the new units in the expansion of a classic substation: an HMI is included in the control panel of the substation while a second HMI is used as the control panel at the bay location. A simple fiber optic connection is used in the expansion, instead of all the wiring required using the pre-existing technology. Increased reliability and cost reduction are achieved. The control hierarchy (SCADA, substation console, local control panel) is accomplished since all the necessary logic is implemented in the processing unit.

Flexible Space Adaptability

The example in Figure 4 also serves to point more advantages of the use of distributed architecture in the expansion of a substation designed with traditional technology. Utilizing I/O modules to capture relay control signals as new bays are added greatly reduces the wiring costs and complexity.

The RTU is connected to the substation devices via one or several I/O modules and fiber optic connections. Location of devices and number of signals to process are not a determining factor in the design of the system, and the number of connections required is significantly reduced.

It is possible to eliminate the second HMI in order to expand the substation control panel. Instead, conventional actuators (pushbuttons, pistol grips, etc.) can be connected to the processing unit via additional I/O modules. Again, a simple fiber optic connection resolves the connections instead of extensive physical wiring.

Optimizing Control Panels and Cabinets

The improvements in local access and connectivity are only part of the advantages of the proposed distributed architecture. The installation of the IRX series IED in a panel or cabinet provides better usage of the space available and drastically reduces the required wiring.

Figures 5 and 6 depict an example where the processing unit and the I/O modules are located in the back panel of the cabinet, closer to the terminal blocks. The HMI is located at its usual location in the front panel. The wiring system is simple and undersized, while standard functions and features are kept.

Figure 5

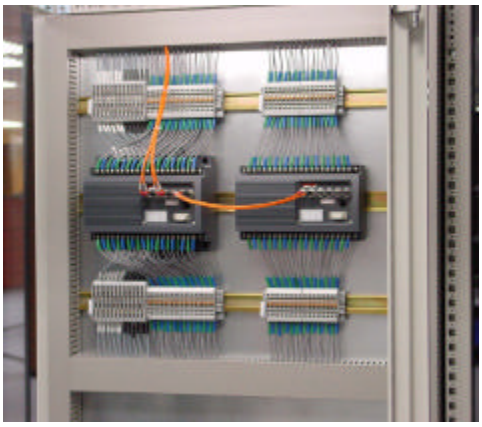


Figure 6

Maintaining Present Practices

The IRX series present an array of new options, without forgetting practices that have been successfully used for decades. One of the obvious requirements in the design of the new line has been the ability to allow the end user to maintain the current installation practices.

Compact installation where the processing unit and the HMI conform a single unit is still possible as shown in Figure 7.

Note that the decision taken in how the units are used at the initial moment is independent on the future usage. The compact installation is easily changed to a distributed setup, without the involvement of the manufacturer. Likewise, distributed units can be reused as compact units without complexity.

Figure 7

FUNCTIONS

The complete IRX Series consists of several processing units oriented to specific applications: feeders (ungrounded, grounded), transformers, transmission lines, etc. Each of the units contains the required functions by each application. Still, the design requires offering the user maximum flexibility. In the concept developed this flexibility means that the maximum number of applications can be achieved with a single processing unit type.

Flexibility and versatility are determined by different functions and models, as well as the characteristics of the hardware and software base of such functions. The previous sections described the hardware features that present the user with innovative characteristics of greater value regarding flexibility. The following sections explain the functional features of the software architecture offering the same values.

Configuration Capabilities

The IRX Series design includes features that allow the user to configure the units to their application and even improve it.

Logic functions, HMI features and information tasks are the key points in configuring the units to both the user and the application.

Logic Functions

The processing units contain two user definable logic blocks by means of elemental primitives:

- Logic gates: AND, OR, XOR...
- Bistables SR, JK, etc.
- Timers
- Counters
- Analog operators: comparators, level detectors, adders, multipliers, etc.

Lock-out functions, operation hierarchy, or automatic controls, information data profiles to be sent via the communication ports towards external systems are also configurable features that will adapt to the application.

The configuration is done using a software package to create a file to be loaded in the IED via communications.

HMI

The HMI modules of the IRX Series have available two interfaces to access the processing unit functions:

- Graphical interface for monitoring and local control operations.
- Alphanumeric interface, used to consult and modify settings. Also have monitoring and control functions.

Both interfaces are user configurable, therefore the appearance and texts will be appropriate for the application, maintaining consistent look and descriptions thorough the system without the need for learning new operation techniques.

Settings

Customizable setting ranges and setting steps is another feature to get the IEDs closer to the user needs. The IRX Series offers the option to customize these values within the system limits to always guarantee the specified accuracy.

Information and Recording

The processing unit includes sequence of events recording (SER) as well as metering history. Event records are composed of time stamped logic signal changes accompanied by the analog values selected by the user. Metering history allows storing the evolution in time of the desired analog magnitudes.

Communications

The communication ability of the IEDs has different purposes. Therefore, the units in the IRX Series are provided with different communications ports having different physical connectors and various protocols to adapt to such purposes.

The IRX Series includes:

- An RS232 port for local connections using a PC. This port is used for maintenance tasks: review and modification of settings, access to stored information (SER, metering history, fault reports, oscillography, etc.), loading configurations, or loading firmware upgrades. This port is located on the processing unit, or on the HMI if available.
- Two serial ports (RS232, RS485, or FO) are available to integrate the unit in protection and control systems. Both ports are located on the processing unit.
- Optical Ethernet connection for UCA 2.0 or IEC 61850 networks are also located on the processing unit.

Connection ports with HMI and I/O modules are not included in this section, since they are considered an internal part of the IED design.

It is possible to communicate simultaneously via the different ports, using three protocols plus UCA2.0 or IEC 61850.

PROGRAMMING TOOLS

The IRX Series is provided with a high level of configuration capabilities. To complete the IRX line, a set of user friendly and efficient software tools has been developed. The PC based tools are part of a larger set of tools including the substation central unit and the engineering console customization packages.

These utilities are developed as a homogeneous engineering package that guides the user through graphical screens and menus during the design of the application. Depending on the goal, the design can be implemented for the whole substation, or for each individual IED. The first option will enable the user to make use of the maximum advantages of the integrated software package.

The modular concept enables the engineer to use parts of previous projects or to modify existing work to the meet current needs.

MAINTENANCE

The ease of maintenance is part of the generic design criteria of flexibility and versatility. Maintenance procedures include, acceptance and receiving testing, commissioning, upgradeability and adaptability.

Installation

The three basic elements of the IRX series architecture are designed to be mounted on standard DIN rail, eliminating the need for screws or additional hardware. This feature enables simple installation and replacement of the units.

To further facilitate replacement, the terminal blocks can be unplugged, allowing the removal of the units while leaving the wiring intact.

Replacement of the HMI or I/O modules is a simple operation and does not require removing the processing module from service, as it continues to operate independently.

The reduction in wiring achieved with this application is one more advantage from a maintenance standpoint, with the added convenience of better reliability and simpler engineering.

Testing

An Integrated Simulator in the IRX Series IEDs provides easy testing. The simulator enables the user to load an external file via communications onto the oscillographic memory. The protective and control elements capture the analog signals from the loaded file instead of the analog channels.

Therefore, is possible to test the IED behavior under previously captured sine waves without the need of external injection test sets.

Upgrades

An important maintenance feature is the ability to modify the basic features of the IED, know as firmware upgrades. The IRX line allows for easy upgrades via communications and the use of a separate software package with all the reliability guarantees.

CONCLUSIONS

After reviewing the initial requirements that have guided the design of the IRX Series, it is possible to summarize the most notable features of the architecture presented in this paper:

1. Flexibility and versatility
2. Focus and adaptability to both the customer and the application
3. Ease of commissioning and maintenance
4. Ability to evolve in the future
5. Suitable functionality
6. Cost effectiveness