GER-3995

The Universal Relay
The Engine for Substation Automation

GE Power Management

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Utilities and manufacturers have been speculating on the feasibility of a Universal Relay™ for a number of years. The ultimate goal for a Universal Relay, from both a technology and economic standpoint, is a unified, modular substation solution that can be networked and seamlessly integrated with existing hardware and/or software regardless of the vendor or communications network.

A key driving force behind the need for the Universal Relay is implementation cost. By having a platform that is open enough to keep pace with today's technology and maintains the modularity and flexibility to allow for future upgrades, utilities can not only preserve their intitial technology investment, they can substantially reduce long-term implementation costs in the substation environment. No more stranded relay investments.

Although listing the attributes of a Universal Relay in theoretical terms is a relatively easy task, for developers the challenge has been in defining the necessary logistical requirements for the ideal Universal Relay. What building blocks are needed to make it as open as possible given today's advancements in technology? How do you design a relay with the flexibility to cover every foreseeable protection application - today and in the future?

As daunting a proposal as this may seem, one need only look at the evolution of PC technology to see how this can be achieved. In just a few short years, the PC has become the general purpose or 'universal' tool and indispensable engine of the information age.

It is worthwhile to note the key concepts which have made the PC a general purpose tool - i.e. a common hardware and software platform, a scalable, modular and upgradable architecture, and a common human-machine-interface (HMI) - are also the key requirements for a universal relay.

However, until recently, an essential element that has been missing from the Universal Relay equation is the development of a communication standard within the utility industry. PC technology overcame that hurdle a number of years ago to the point where PCs are so open, they can function in virtually any environment, communicate with any other device on a network, and run almost any software application without the need for customized interfaces or configurations.

The utility industry has now followed suit with the development of an international standard that is bringing the Universal Relay to the forefront as the utility's general purpose tool and indispensable engine of the substation environment.

**Universal Relay* is a trademark of GE Power Management

Open Communications Protocols

In today's open systems the ability to share data seamlessly through company-wide networks is the key to increasing efficiency and reducing costs as well as enhancing open connectivity between a company's related functional areas. This is especially true in the utility industry, where organizations have been grappling with a range of proprietary hardware and software products that can be neither integrated nor upgraded at a reasonable cost and/or effort. Special communications interfaces or gateways must be used to connect any new equipment to an existing data network if a utility wants to expand beyond its proprietary equipment.

The effort to achieve a common protocol that provides high-speed peer-to-peer communications as well as device interoperability for substation automation is being driven in North America by a select group of international utilities as well as the manufacturers. This is being done through EPRI (Electric Power Research Institute) in conjunction with the relevant standards-related groups in the IEEE and IEC committees.

With the progress being made by EPRI in establishing open-systems communication protocols, hardware and software from different vendors can be linked and progressively integrated over time, thereby providing a means to cost-effectively upgrade as needs and technology develops.

The proposed solution for the substation is implemented based on existing standards. These standards include the Manufacturing Message Specification (MMS) and Ethernet as the data link and the physical layer. The intent is that the substation communication will be UCA (Utility Communications Architecture)-compliant in order to eliminate gateways, and allow maximum interconnectivity among devices at minimum cost.

The development and increasing application of the proposed solution has the potential for saving millions of dollars in development costs for utilities and manufacturers by eliminating the need for protocol converters (both hardware and software) when integrating devices from different manufacturers. Also because of the high-speed peer-to-peer communications LAN (local area network) a great deal of inter-device control wiring can be eliminated by performing inter-device control signaling over the LAN.

UCA Version 2

EPRI's UCA™ Version 1 protocol was introduced in 1991 and represented the first comprehensive suite of open communication protocols to meet the specific needs of the electric utility industry. In 1997, the new UCA Version 2 standard substantially expands the versatility of UCA by including internet compatibility and specifying a common interface standard for electric, gas and water utility systems.

UCA2, in being able to provide an interface to different vendors' products, ensures that equipment from multiple sources can interface. In addition, it can support existing and future network protocols.

EPRI's work to date in this area has established that an open communication protocol allows utilities to improve operating and business decisions based on real-time availability of data, combine different local and wide area media with minimal modification costs, reduce system implementation time and cost through using standardized utility devices and eliminate redundant storage, since information can be accessed wherever it resides.

With communication protocols well on their way to becoming standardized, a major stumbling block to the Universal Relay has been removed. It is now time for it to move from the drawing board into the hands of the utilities.

The evolution of the relay

When GE Power Management embarked on an ambitious design program to develop a "next generation" family of protection relays, it relied on the same concepts and technologies that have driven the desktop personal computer (PC) market to such phenomenal heights in terms of performance and cost effectiveness to make it a general purpose or "universal" tool and the engine of the information age.

The aim of the program was to provide utilities with a common tool for protection, metering, monitoring and control across an entire power system, one that would serve as the universal engine for substation automation.

In order to understand where the technology stands today, perhaps it's best to look at the evolution and functionality of protective relays over the years.

IEEE defines a protective relay as " a relay whose function is to detect defective lines or apparatus or other power system conditions of an abnormal or dangerous nature and to initiate appropriate control circuit action" (IEEE 100-1984). This definition could best be classified as general rather than 'universal' in nature.

Traditionally, manufacturers of protective relay devices have produced different designs that are specific to the protection of generation, transmission, distribution and industrial equipment. This approach has its roots from the days of electromechanical and solid-state relay designs, where the widely varying complexities associated with each type of protection had to be implemented in proprietary hardware configurations. For example, there was a significant difference in cost and complexity between an overcurrent relay used for feeder protection and a distance relay used for protection of EHV (extreme high voltage) lines.

This leads us to an essential requirement of a Universal Relay. A Universal Relay must at minimum, be capable of providing protection for all the sectors of the power system - from simple overcurrent protection for feeders to high-speed distance protection for EHV lines. More importantly, it must offer a cost-effective solution for both.

Development milestones

One key contributor to the feasibility of the universal relay design has been the advancements made in digital technology and the evolution of microprocessors, as well as the proliferation of numerical/digital relays within the industry.

One only need look at the PC industry to see that the power and performance of microprocessors have increased dramatically while prices have decreased. In fact, the technology is now at the point where the performance requirements of a distance relay and the cost/performance requirements of a feeder relay can be met by the same microprocessor and digital technology.

The proliferation of numerical relays, also has allowed manufacturers to develop and perfect software for protective relaying devices across a power system.

By leveraging the advancements of microprocessor and digital technology, and combining those with the array of existing and proven software developments, the 'universal relay' becomes the logical outcome.

Just as the PC is a general-purpose tool that can perform numerous tasks by running different application programs on the same platform, so can a numerical relay built on a common platform become a general purpose or 'universal' protection device by running different protection software for the apparatus being protected.

As a general purpose tool, there are a number of essential functional blocks that must be incorporated into the design of a Universal Relay.

Universal Relay building blocks

Most modern numerical, microprocessor based relays are comprised of a core set of functional blocks:

A. Algorithmic and control logic processing, usually performed by the main 'protection' microprocessor and often referred to as the CPU (central processing unit). Most numerical relays have multiple processors for different functions.

B. Power system current and voltage acquisition, usually performed by a dedicated digital signal processor (DSP) in conjunction with an analog-to-digital data acquisition system and interposing current and voltage transformers.

C. Digital inputs and outputs for control interfaces, usually required to handle a variety of current and voltage ratings as well as actuation speed, actuation thresholds and different output types (e.g. Form-A, Form-C, Solid-State).

D. Analog inputs and outputs for interfacing to transducer and SCADA (Supervisory Control & Data Acquisition) systems, usually required to sense or output dcmA currents.

E. Communications to station computers or SCADA systems, usually requiring a variety of physical interfaces (e.g. RS485, Fiber Optical, etc.) as well as a variety of protocols (e.g. Modbus, DNP, IEC-870-5, UCA 2.0, etc.)

F. Local Human Machine Interface (HMI) for local operator control and device status annunciation.

G. Power supply circuitry for control power, usually required to support a wide range of AC and DC voltage inputs (e.g. 24-300 VDC, 20-265 VAC).

The design of a universal relay requires an architecture that can accommodate all of the above functional blocks in a modular manner and allow for scalability, flexibility, and upgradability in a cost effective manner for all applications.

The biggest challenge for relay designers is the ‘cost effective manner’. The risk they have faced in the past is creating an architecture with all of the above attributes where the base cost of the platform is too high for the more cost sensitive applications such as feeder protection.

Today, this has been resolved as a result of cost reductions inherent in the production of a common platform for all applications. Like the PC industry, common components such as power supplies, network cards and disk drives continue to drop in price, while delivering ever-increasing performance levels.

While protective relay production is nowhere near the volume of PCs, a next generation relay platform based on a modular architecture which can accommodate all applications will yield significant development and manufacturing cost reductions.

The Universal Relay Architecture

In defining what a Universal Relay needs to do, it is important to understand the architectural elements that perform the above mentioned functions.

Modularity

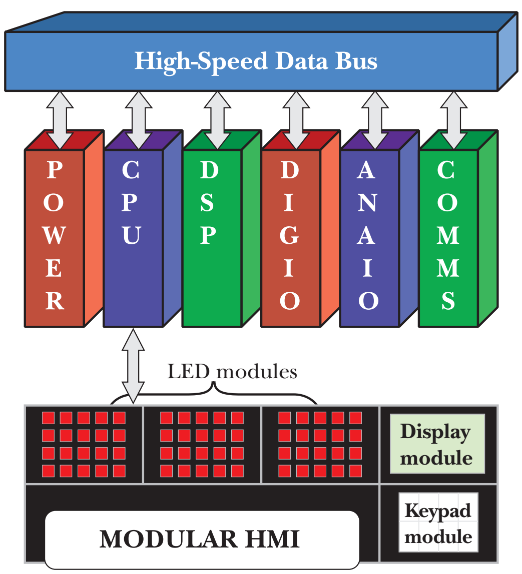
On the hardware side, modularity is achieved through a plug-in card system similar to that found in programmable logic controllers (PLCs) as well as PCs. A key element in the successful performance of such a system is the high-speed parallel bus which provides the modules with a common power connection and high-speed data interface to the master processor (CPU) as well as to each other. Figure 1 shows such a system with all the core functional blocks implemented as modules.

Figure 2 represents a physical realization of the modular architecture used in the design of GE Power Management’s Universal Relay - a 19-inch rack-mount platform, 4 rack units in height, capable of accepting up to 16 plug-in modules.

Modules plug into a high-speed data bus capable of data transfer rates as high has 80 Mbytes/sec. The high-speed bus should be completely asynchronous, thus allowing modules to transfer data at rates appropriate to their function. This is crucial in order to maintain a simple, low-cost interface for all modules. The bus should be capable of supporting both parallel and serial high-speed communications simultaneously (up to 10Mbps serial) which allows those modules which must transfer data as quickly as possible to use the high-speed parallel bus (80 Mbytes/sec), while others can use the serial bus to avoid communication bottlenecks.

One of the key technical requirements of such a system for protective relaying applications is that the modules must be capable of being completely drawn out or inserted without disturbing field wiring which is terminated at the rear of the unit (see Figure 3).

Modularity can also be applied at the sub-mod-



POWER = Power Supply Mode
CPU = Main Microprocessor Module
DSP = Digital Signal Processor & Magnetics
DIGIO = Digital Input/Output Module
ANAIO = Analog I/O Module
COMMS = Communications Module

Figure 1 *- System configuration showing a high-speed data bus and modules with a common power connection and high-speed data interface to the zcpu.*

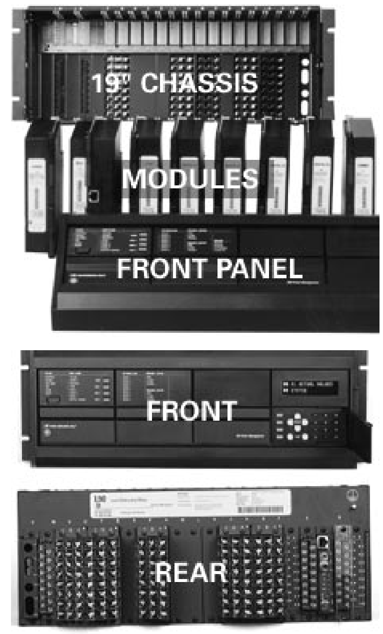


Figure 2 *- A working example of the modular architecture found in a* ***Universal Relay.***

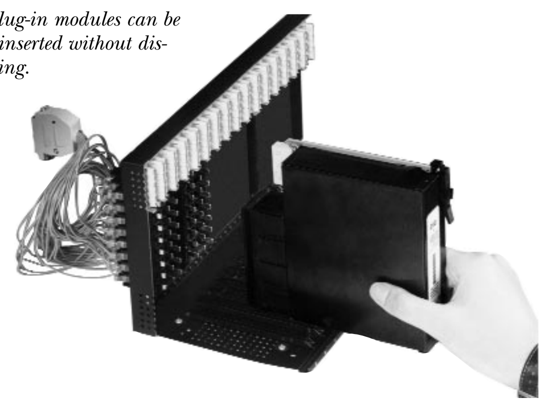


Figure 3*- Plug-in modules can be removed or inserted without disturbing wiring.*

ule level (Figure 4). Configurable input/output (I/O) combinations can accept plug-in sub-modules, which means that each sub-module can be configured for virtually any type of I/O interface desired, to meet both present and future demands. This gives the relay a 'universal' interface capability.

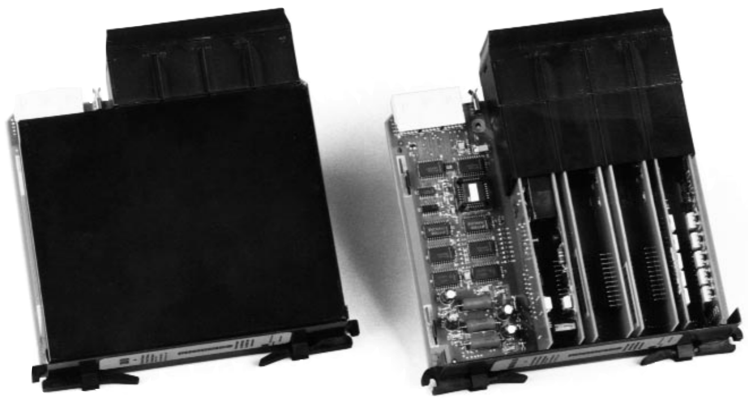


Figure 4 *- Configurability at a sub-module level.*

Scalability and flexibility

A modular architecture of this type allows for both scalability and flexibility. In particular, scalability is found in the ability to configure the relay from minimum to maximum I/O capability according to the particular requirements. The flexibility lies in the ability to add modules configured with the desired sub-module I/O. This allows for maximum flexibility when interfacing to the variety of control and protection applications in the power system (Figure 5).

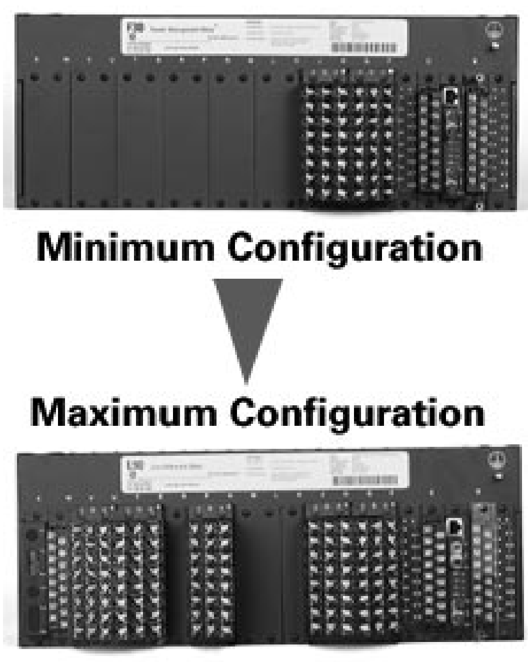


Figure 5 *- An example showing minimum and maximum module I/O capability.*

Upgradability and Enhancements

Another obvious benefit of this architecture is the ability of users to upgrade or enhance their relay simply by replacing or adding modules. For example:

* Upgrading from a twisted pair copper wire communications interface to high-speed fiber optics communications.

* Enhancing a transformer protection application by adding an Analog I/O (ANIO) module with the sub-modules to detect geomagnetic induced currents, sense and adapt to tap-position, perform on-load tap-changer control, or detect partial discharge activity.

* Upgrading the CPU module for more powerful microprocessor technology allowing for more sophisticated and protection algorithms (e.g. "Fuzzy Logic", "Neural Networks", "Adaptive").

* Enhancing the metering capability of the relay by adding a second DSP module with current and voltage transformer sub-modules capable of revenue class metering accuracy.

* Enhancing the control capabilities by adding a Digital I/O (DIGIO) module with customized labeling to customize the reporting of events.

* Enhancing the HMI capabilities by adding an LED module with customized labeling to customize event reporting.

Modular Software

Scalability and flexibility issues are not exclusive to hardware.

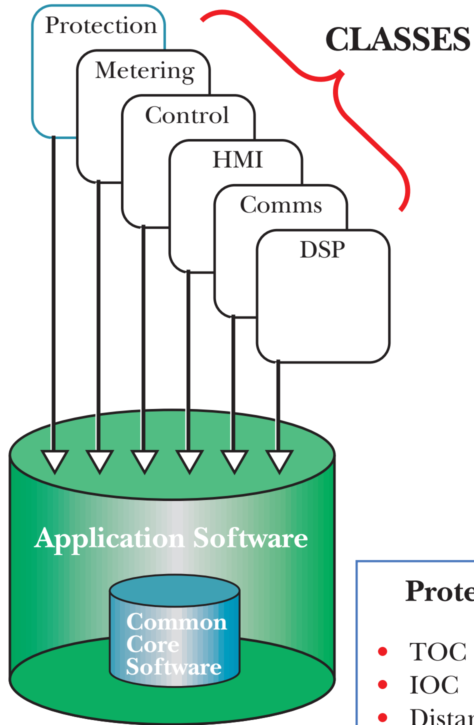
Software must be able to support the same features. In fact, the software has its own form of modularity based on functionality. These include:

* Protection elements
* Programmable logic and I/O control
* Metering
* Data and Event capture/storage
* Digital signal processing
* HMI control
* Communications

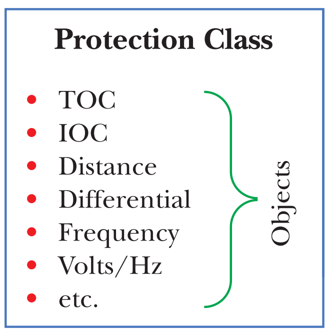
The key advancement in software engineering that has come to dominate the software industry is Object Oriented Programming and Design (OOP/OOD). This involves the use of 'objects' and 'classes'. By using this concept one can create a protection class and objects of the class such as Time Overcurrent (TOC), Instantaneous Overcurrent (IOC), Current Differential, Under Voltage, Over Voltage, Under Frequency, Distance Mho, Distance Quadrilateral, etc. These represent software modules that are completely self-contained or 'encapsulated' (Figures 6a and 6b).

The same can be done for metering, programmable logic and I/O control functions, HMI and communications or, for that matter, any functional entity in the system.

Therefore, the software architecture is able to offer



Figures 6a and 6b - *The OOP/OOD concept uses objects and classes to create self-contained software modules.*



scalability and flexibility: scalability in that the number of objects in an application are scalable (e.g. multiple IOC elements); flexibility in that objects can be combined to create custom combinations to suit the application (e.g. TOC, IOC, Distance Underfrequency and Directional IOC).

In combining these attributes - modularity, scalability, flexibility, upgradability and modular software - the capability is there to run a wide variety of applications on a common platform. Figure 7 shows the concept of a common platform Universal Relay capable of running multiple applications.

The benefits

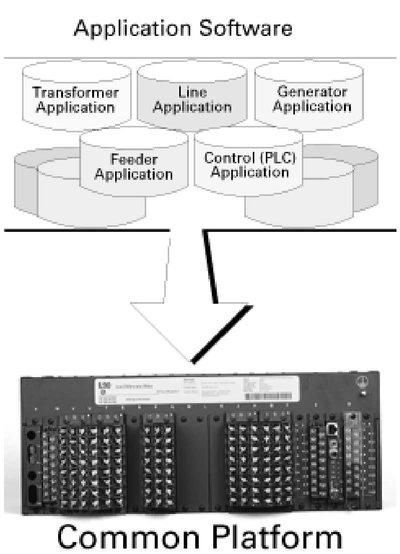


Figure 7 - *The elements of the Universal Relay platform*

Overall, the ability to standardize on one hardware configuration that can address the majority of specific applications is a major potential benefit to users. As a common platform, the Universal Relay can be used to run any variety of the appropriate application software.

Standardizing on a common platform also potentially reduces engineering and commissioning costs through simplified wiring diagrams, reduced drafting expenses, simplified commissioning and test procedures, as well as reduced learning time when applying the device to different applications.

The key element which results from a common platform approach in simple terms is that of a 'common look and feel' across the entire family of applications - the ideal scenario for substation automation.

The Universal Relay's role in substation automation

As mentioned earlier, utilities worldwide have been clamoring for a standard that will allow different devices from different manufacturers to communicate with a common protocol and to interoperate. Now that the standard issue is being resolved, one can look to add value by networking protective relaying devices. This is achieved by leveraging their ability to communicate among themselves (i.e. peer-to-peer) and to the station interface.

Since the Universal Relay offers a modular hardware and software architecture that is scalable, flexible, and upgradable, as well as advanced peer-to-peer communications, it can accommodate the requirements of any substation automation proposal.

In addition, the configurable object oriented software can handle both new and legacy communications protocols, which means a Univeral Relay can coexist in today's environments, as well as handle any future migration to Ethernet or other future technology without incurring the significant investments normally associated with system conversions or upgrades.

As performance and functional requirements evolve to take advantage of the new possibilities brought about by high-speed peer-to-peer communications the Universal Relay can just as easily evolve to remain in-step with users' requirements and budgets.

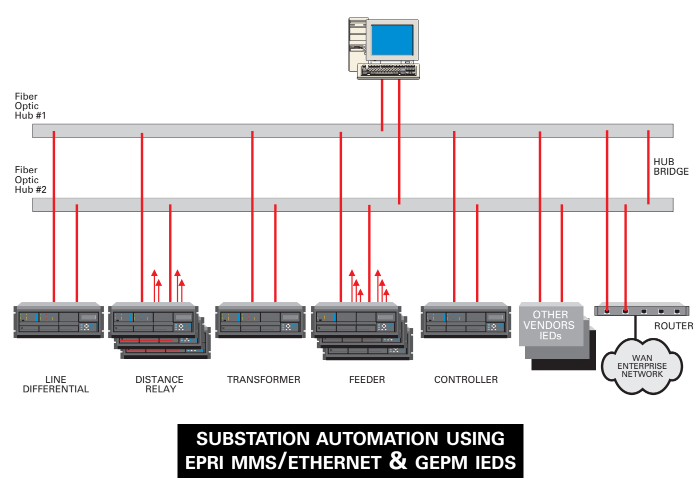


Figure 8 - *Schematic of entire Universal Relay setup, from workstation to relays.*

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