Oil Shale, 2005, Vol. 22, No. 2 Special
pp. 209-216
ISSN 0208-189X

https://doi.org/10.3176/oil.2005.2S.13

INTEGRATION OF CONTROL AND PROTECTION SYSTEMS IN POWER NETWORKS

R. BERKMAN[*1], M. MELDORF[*2], H. TAMMOJA[*3]

Department of Electrical Power Engineering,
Tallinn University of Technology
5, Ehitajate Rd., Tallinn 19086, Estonia

This paper describes the development of substation communication protocols from the Estonian point of view. The usage of IEC 61850 and other communication protocols based on TCP/IP+Ethernet are discussed among other topics. Relay settings and disturbance recorders could be accessed from the Internet Explorer via local intranet connection. The first project in Estonia is already connected to this network. This provides a very easy and efficient solution for relay engineers for fast fault analysis. The communication port for this system is separate from the communication port to the SCADA for redundancy reasons.

Introduction

The kernel of the operational control of the electrical network is the dispatch system that enables to supervise the operation of the network, to collect measuring data and signals, to process information about events and alarms, and to control devices, as well as to change the relay settings. The necessary information for operational control originates mostly from the substations and stand-alone switching devices, where the data acquisition between the IED-s (Intelligent Electronic Device) is carried out. The IED-s provide all the protection and system automation functions at the substation required by the customer.

The development of substation automation systems dates back to the early seventies when first all-digital substation monitoring control and protection systems were proposed. The earliest design of microprocessor relays concentrated on the protection functions, when communication was totally a secondary issue. For communication with the outside world a low-priority loop was provided. The need to obtain more information from the relay increased the load on the communications processing loop.

[1*] Corresponding author: e-mail *rait.berkman@ee.abb.com*
[2*] E-mail *mati.meldorf@ttu.ee*
[3*] E-mail *heiki.tammoja@ttu.ee*

During the years, several different substation automation philosophies were proposed, but it was not until late eighties that the communication and processing technology became mature enough to start developing cost-effective systems. As a result, several efforts are under way to implement such systems, and these efforts are well supported by the development of needed standards. [1]

The communication technology has now become the key for the success of substation automation, which can reduce the cost of substation protection and control devices, and therefore it has become very important to electric power companies. Interoperability between protective relays from different manufacturers in the substation becomes a necessity in order to achieve substation level interlocking, protection and control functions and improve the efficiency of microprocessor based on relay application. The process of relay integration is slowed down by the fact that each relay manufacturer uses a proprietary (different) communication protocol and user interface software (SPA, LON, Modbus, Profibus, etc.). This reduces the benefits of integration because of the need for additional hardware, such as protocol converters and software (user interface programs). Therefore the IEC recognized the need for a new standard interface to the new "protection IEDs" produced by different vendors. IEC TC57 and IEC TC95 set up a working group, which developed a standard for the "Informative interface of protection equipment" (IEC 60870-5-103) [2]. Today this protocol is widely supported by different vendors, but the "private range" makes it difficult to integrate together IED-s of different vendors. This increases considerably the cost of commissioning because the use of generic services in the extension part (private range) is time consuming due to its complexity and low performance.

The need for interoperable communication protocol that has standardized information models for all kind of protection relays led to the foundation of IEC 61850 standard that is the collaboration between the IEC and the ANSI world. IEC 61850 has been created by users and manufacturers alike. The internationally agreed purpose of this standard is to obtain an integrated communication solution for substations. Users have access to the open systems based on Ethernet communication technology. The object-oriented structure covers protection and control functions and thus makes substation management more efficient. The IEC 61850 standard defines the communication between intelligent electronic devices in substations, supporting the following applications:

- Protection and control
- Integration of innovative sensor and switch technologies
- Metering, supervisory control and data acquisition
- Remote monitoring and fault diagnosis
- Automated dispatch and control
- Asset management
- Condition monitoring and diagnosis

- IEC 61850 provides:
- Standardized information models for all kinds of protection relays, controllers, circuit breakers, transformers, etc.
- Information exchange methods to access data of the information models; report sequences of events, log historical data, control devices, sampled value distribution, fast peer-to-peer process data exchange, etc.
- A unified system configuration language (XML-based) and device online self-description.

Future Trends in Substation Communication

Utilities and vendors alike benefit from IEC 61850 because it:

- is a global standard,
- reduces engineering, operation and maintenance costs,
- uses mainstream technologies like Ethernet, TCP/IP, Object modeling and XML,
- is highly flexible and scalable,
- is a seamless solution for cross-application requirements,
- reduces the diversity of solutions to be supported.

The communication system has to allow the mixture of devices from different suppliers. Traditionally, this request came by the wish for independent back-up functions, especially for protection. Today, the independence from suppliers is a strong argument in general.

Figure 1 shows an example of a typical future hierarchical substation automation system [3]. At process level there are process interfaces, hard-wired in the past and serially linked by the process bus in the future. The protection and control devices are connected by the interbay/station bus. At station level, there is very often a station computer with HMI (human machine interface) and a gateway to the control center at a higher network level.

The focus of IEC 61850 is the support of substation automation functions by information models and information exchange methods for (the number in brackets refers to Fig. 1):

- sampled value exchange for current and voltage sensors (*1*)
- fast exchange of I/O data for protection and control, e. g., tripping and blocking (*2*)
- control signals (3)
- engineering and configuration (*4*)
- monitoring and supervision (*5*)
- control-center communication (*6*)
- time synchronization

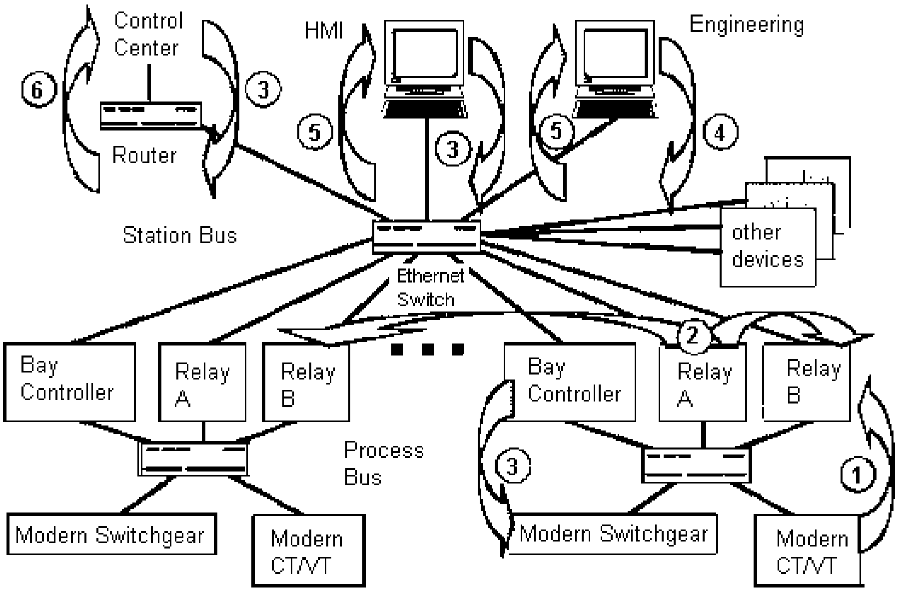

Fig. 1. Modern substation technology [3]

Systems that only produce, transmit, or distribute electric power need more and more – seamlessly supervised – automation systems that require little or no human intervention for the configuration and operation. Technologies bundled into the electric power system, therefore, have to include system configuration, protection and control equipment, as well as interfaces to supervisory control and data acquisition (SCADA) of control centers. Other applications that have already started to rely on these standards are: remote monitoring and fault diagnosis, power quality, automated dispatch and control, site optimization of electrical/thermal outputs, asset management, as well as condition monitoring, and diagnosis. [3]

Development Trends in the Estonian Substation Communication

IEC61850 seems to be the most beneficial solution for future communication networks in substation. This will probably be also a trend in the Estonian national power company. However, for example in Estonia (generally in all Baltic countries), one communication interface per terminal unit is not enough for the utility. There has to be a separate modem connection between relay protection devices. This modem connection is not related to the dispatch center, but it is meant to be used by relay engineers so that they can read disturbance recorders and change relay settings from the office.

For example, in the main grid all new and existing devices are connected to one incoming telephone line for remote communication including:

- all protection relays and automation devices
- automatic reserve switching terminals
- local alarm center
- voltage regulators
- external disturbance recorders
- 0.4 kV AC control terminal
- DC battery charging terminals

All modems have to be pre-configured, and all devices connected to the service modem have to be accessible by one software only. This modem connection to the devices has to be totally independent from other systems. This is a preventive measure to make it possible to read disturbance recorders from the substation, when the communication lines to the dispatch center are broken. Even though IEC61850 is enabling these functionalities, it is not acceptable to use this protocol for redundancy reasons. It would have to be a separate communication port.

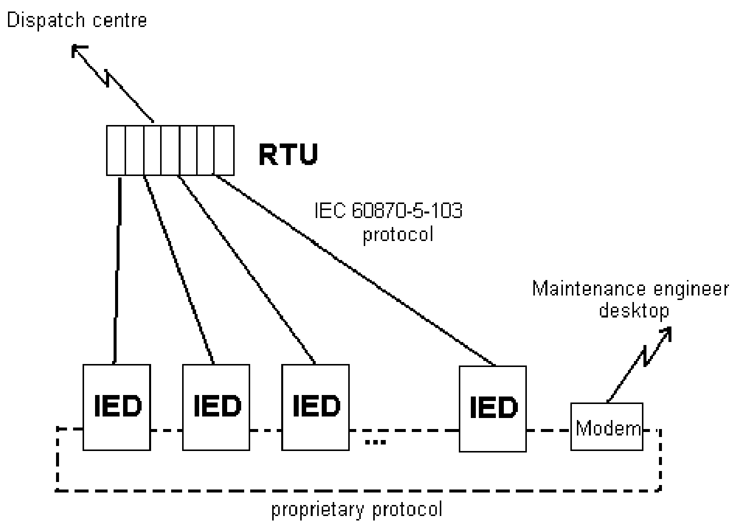

Fig. 2. Two communication ports for IED-s

The implementation of Intranet technologies in protection and control systems can enable free and flexible acquisition of power system information at the appropriate location. In the next example (Fig. 2) Intranet is utilized for remote communication to the desktop of the maintenance engineer. IEC 60870-5-103 protocol is still the primary protocol communicating with Remote Terminal Unit, but local Intranet is used for reading the disturbance recorders, relay settings and events from the relay unit. It is also possible to change the settings and even to control the breakers *via* Intranet, but for security reasons it is forbidden in the relays.

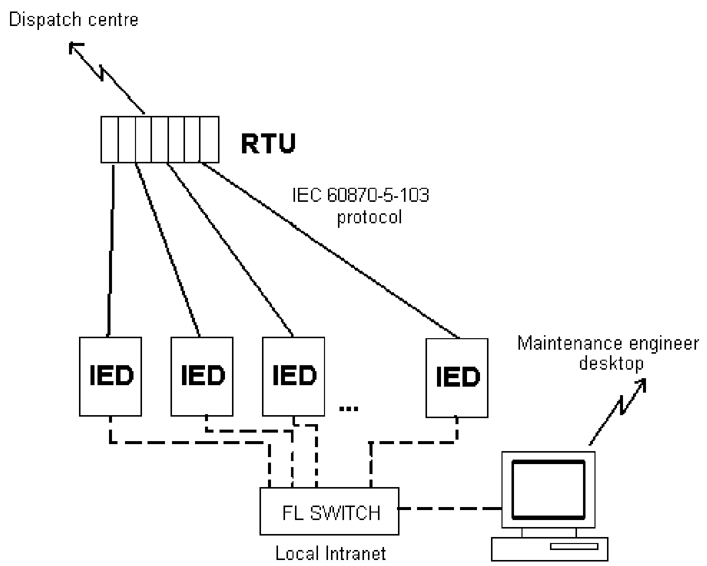

Fig. 3. Two communication ports with Intranet interface for maintenance desktop engineer

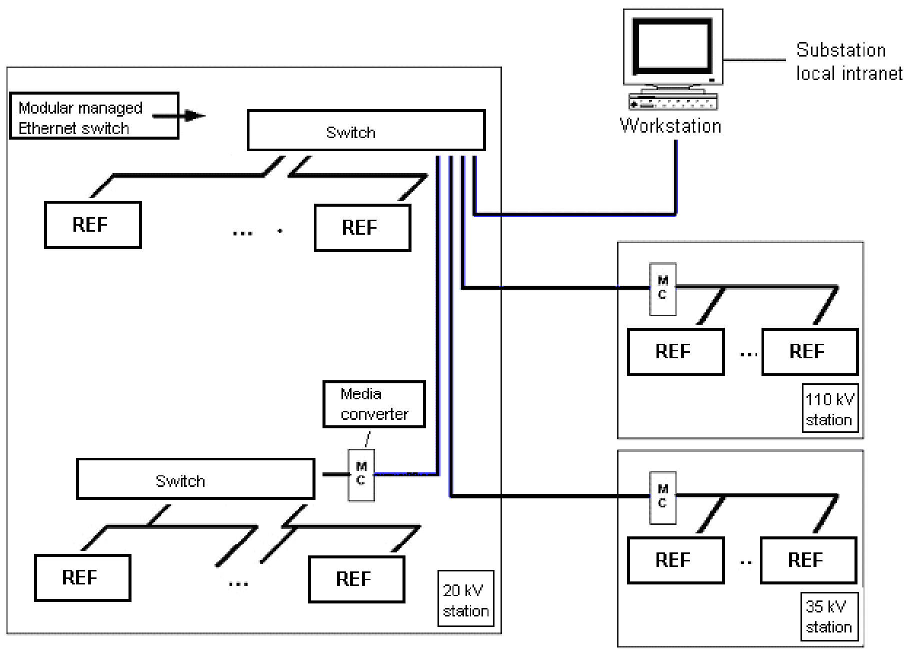

Fig. 4. An example substation local intranet system in Estonia

The importance of the second communication loop expresses itself in many occasions. For example there are constant changes in the operation mode of the network, which require changes in relay settings. In the substations without remote modem connection it takes many working hours for the maintenance people to travel to the site for realizing the changes. This would considerably raise the costs of the relay maintenance. When the faults occur in the network, it is important for fault analysis to be able to read the disturbance recorder files from the relays. The signals that come to the dispatch center are usually not sufficient for clarifying all the reasons of the fault. Besides, the dispatcher has no real time for this, and the real reasons would always have to be clarified by the maintenance staff. It is easy to use remote modem connection for the purpose of analyzing and clarifying the fault within half an hour. This need may generally occur once or twice a week, especially during autumn and spring.

In Figure 4 it is shown how the local intranet is utilized for reading the settings and disturbance recorders from a substation *via* separate TCP/IP port. This solution is possible due to embedded WEB server (in this case ABB feeder terminal REF 542+). It is meant for monitoring purposes (WEBREF).

The Ethernet port of the main module provides connectivity to the WEB. By using a standard PC with commercial WEB browser, the user can gain access to the substation units using WEB facilities. Monitoring the substation units is then possible from everywhere; the implemented security mechanism prevents unwanted accesses and guarantees the required safety. As soon as the browser is connected to the REF 542+ unit, the switchgear overview is displayed. From here, the user can scroll through the single line diagram (see Fig. 5).

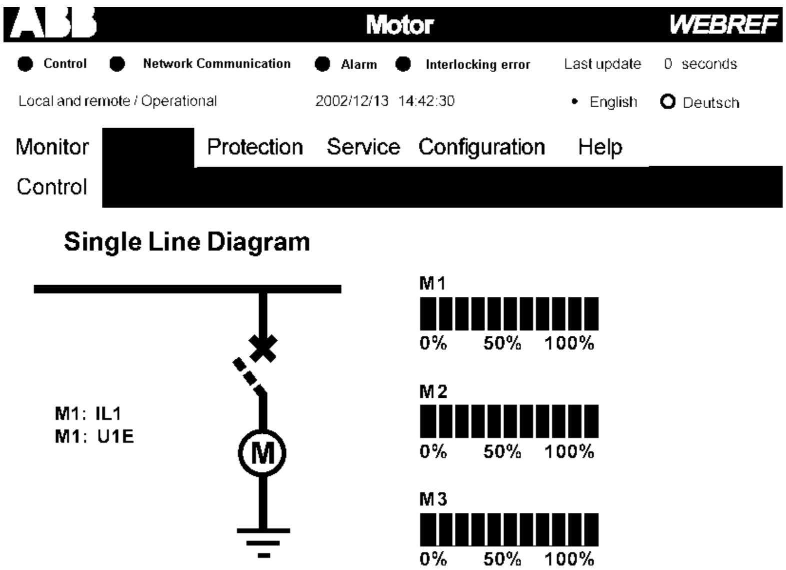

Fig. 5. REF 542+ main page as seen from the internet browser

Clicking on the address button, the specific REF 542+ unit single line diagram is loaded, with all the information that would be normally available only when standing in front of the HMI. REF 542+ data is available in read mode only. WEBREF makes also available the possibility to send SMS messages *via* the GSM network upon specific, user defined condition (trips, alarms, etc.). A suitable GSM modem must then be connected to the mainboard module.

This kind of solution in Estonia is known as one of the first ones in the world using intranet for this purpose. Hopefully this project will prove itself to be a successful one, and this type of solution can be used in all the future projects.

Conclusions

The future trends of substation communication seem to be based on TCP/IP+Ethernet platform. This will bring many benefits for substation automation. Utilities and vendors take advantage of the new seamless use of the standards, and make the electric power systems safer and more efficient than before – all critical information is available (at any time and anywhere), is reliable, and could be easily understood when making control decisions.

REFERENCES

1. *Kezunovic, M.* Future Trends in Protective Relaying, Substation Automation, Testing and Related Standardization. Hong Kong Polytechnic University, Hong Kong, Lecture, Nov. 2002.
2. *Shepard, B., Janssen, M. C., Schubert, H.* Standardized Communications in Substations. IEE DPSP Conference, April 9–12, Amsterdam, Conference Manual, pp. 270–274.
3. Karlheinz Schwartz IEC 61850, IEC 61400-25 and IEC 61970.

Received November 8, 2004