

SUBSTATION CONTROL SYSTEM- CROATIAN DISTRIBUTION UTILITIES EXPERINECES

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ABSTRACT

Modern numerical protection relays and feeder terminals feature at least one system communication port for data connection with substation monitoring or substation control system, using standard or private communication protocol. Presented in paper are experiences and some solutions in practice of design. Implementation of supervision and control system in power distribution based on IEC60870-5-103 communication protocol with feeder terminals (IED) and numerical protection devices of different manufacture.

KEY WORDS

Protection and control, feeder terminal (IED), substation control system, IEC60870-5-103, substation monitoring system

1. Introduction

Modern requirements for system operation in distribution utilities, demands on IED's and control system, which must fulfill requirements for fast and reliable acceptance and distribution of data. These requirements are needed for running reliable and operation of medium voltage network, fault clearing, switching operation and analysis. Furthermore, control system must be open, flexible, easily adjustable and modular.

When using the feeder terminal as basic part of substation control system, design of system must cover for weakness and restrictions of IEC60870-5-103 protocol. Namely specification of the data differ by different manufacturers of numeric relay protection, therefore adjustments inside the software of the system is necessary. Lacks of support inside the protocol for retrieval of settings and disturbance records often is solved by applying another system interface for connection to substation monitoring system.

1.1 Numerical relays for protection and control

Numerical devices for protection and control functions (feeder terminals) have proved in our medium

voltage substations as practical reliable and cost-effective solution for system protection and control.

Along with improvement due to rapid increasing processor power, miniaturization and other trends in electronic technology, multifunction numerical relays are developing in three main function areas:

- a) Regarding supported protection functions: noticeable is increase in number of supported functions for protection, measuring, logical programming, local signaling and other auxiliary functions, comprised in same or smaller hardware. Memory is enlarged for fault data and recording and for event listing. Software tools are refined, running more clearly and reliable. Tools for fault analysis and disturbance records become more comprehensive.
- b) Regarding supervision and control functions: more inputs/outputs for status signaling and control of isolator switches, ground switches and circuit breakers in bay. More processing power for interlocked control, monitoring of measuring, circuits and equipment and achieving other information.
- c) In communication area, the biggest improvements are noticeable. Today we use feeder terminals, featuring two and often three communication ports: at least one is for connection via optical fiber. IED's are capable to send information in more different communication protocols where usually one is communication protocol developed by manufacturer and rest of them are industrial and/or standard. Manufacturer of numerical relays supports communication system engineering with communication converters and with comprehensive technical documentation. In addition, standard documents on communication protocols are available.

Development and engineering of control system based on feeder terminals few years ago was slow process, because of restrictions of protection communication systems.

Manufacturers of numerical relays made their private solutions for protocols (along with data transfer media) in complete solution for protection and control system. In terms of modern software solutions and widely open market, with philosophy of modular and partial development of substation secondary system, manufacturers are forced to ensure modular and open system on all levels. Still with development of own communication systems, many of them use so called “industrial” (Profibus, Modbus) and standard (IEC60870-5-103, IEC61850) communication protocols.

1.2 Communication with numerical relays

Most manufacturers of numerical relays today support standard communication protocol IEC60870-5-103 for communication link among IED’s and higher level control system. In wide use is also standard communication protocol MODBUS, taken over from automatic systems based on PLC devices.

Specifications of IEC60870-5-103 protocol [1], define layers of information for communication with numerical relays, define data and describe procedures for data transmission and exchange.

Main advantage of IEC60870-5-103 protocol is that it is single protocol supported today by IED’s of most manufacturers. Also, it is open and comprehensively documented by IEC and by manufacturers of IED’s [2], [3]. Some of them have a long time experience in practice, as they factory protocols from start are compatible with IEC (for example Siemens with protocol VDEW). Advantage is also that protocol is backed-up by authority of IEC that is to ensure that development of IEC60870-5-103 protocol will follow in controlled direction, defined by consensus of major manufacturers, on benefit of end user (already proved with preparation for new IEC61850 standard [4]).

Main disadvantages of IEC60870-5-103 protocol are:

- a) It supports insufficient scope of data from modern feeder terminals. Standardization is achieved by separating data (according on characteristics of data) within basic and free (private) part of communication protocol. In basic area, data is defined, but it covers for common data (measurements, trip logs and signalization). Most of specific data from respective IED is put in private area of protocol, designed specifically and by that, subset of manufacturer specifics IEC data is made, described in its own technical documentation.
- b) Communication protocol does not include transfer of detailed “protection” data. For example, IED settings detailed list of events, fault data and disturbance records. Sometimes these data are transferred within private area of protocol, but sometimes these are not supported.

2. Characteristics of modern supervision and control system based on feeder terminals

Since 1995, Koncar has installed numerical protection relays and developed modern supervision and control systems based on data collected from numerical relays (started with GEC-ALSTOM K-series, ABB SPA). In 1995-1999, manufacturers of numerical relays supported only their own communication protocol used to transfer closed scope of data chosen by manufacturer system engineers. Factory communication protocol specified also its specific data syntax, data transfer procedure and transmission media. Specification of protocol often was not for open distribution. Design and engineering of control system that should communicate with different relays and with higher control, demands developments of communication hardware and software developed according to specific generation and manufacture of numerical relays.

Based on modern numerical protection devices, as mentioned before, we developed and successfully tested new open source software base for the substation control system and made good base for open system in the future.

New software had to accomplish for following main demands:

- a) simple adaptation of support software to transfer data with numerical relays of different manufacturers and communications protocols (open system),
- b) supported on-line communication and data transfer with relays of different manufacture and communication in the same station computer,
- c) large information throughput of the system, with possibility of batch processing and transmission increased quantities of information from increased numbers of connected numerical relays,
- d) open and easy upgradeable, while still reliably running control software,
- e) system builds using standard communications hardware (standard serial communication interface, network cards, converters etc.)
- f) man-machine interface (MMI) of the system must look same as in previous solutions, with possibility to upgrade to MMI of newer generation,
- g) data transfer with higher level of control must be compatible with existent solutions (IEC60870-5-101 etc), and easy upgradeable.

New software platform based on system communication subprograms fulfilled specified requirements. The programs are in computer independent but interconnected,

transferring data with numerical relays consequently convert, exchange, bank up into database and refer to higher control center, user interface, second computer (hot standby) etc. Modular organization of the system communication programs provides good adjustability and expansion. Modern PC computer for industrial use, provide substantial hardware basis. Power of processors and communication hardware following trends of development in IT set sufficient basis for expected future expansion.

Relay protection engineer in medium voltage substations is to provide support to programmers of software when engineering the control system. He is also protection specialist, whose job is to program logic and control functions, auxiliary and signaling functions, local MMI, communication interfaces. In addition, he is needed to prepare and engineer base of the control system (make decisions about control and interlocking, range for alarm signalization, measurements to be transmitted to higher level of control etc). IEC data that numerical relays supports are often described in details, inside technical documentation of relays. Furthermore, named specialist must have basic knowledge of communication protocols. In order to properly sets communication subunits of numerical relay and take action in case of some problem or malfunction. Mentioned range of tasks puts great pressure on protection specialist for relays in medium voltage substation. It is direct consequence of the fact that all mentioned information are accomplished in within feeder terminal that is still considered as “protection relay”.

2.1 SCS in MV SS 35/10(20) kV Vodice

In medium voltage substation 35/10(20) kV Vodice, substation control system was installed and put in service in 03/2003 (Fig.1). Investor’s choice was installation of feeder terminals (Siemens 7SJ63 [2]), complying to requirements of relay protection in distribution utilities, as well as requirements on control, signalization and data transfer. Terminal feeders feature MMI with LED’s, graphical LCD and group of keys for local service. Relays have front (DIGSI interface) and two rear (control and monitoring system interface) communication ports. Software package DIGSI 4 supports access to terminal feeder and enables easy access to function settings using front port on the relay. Communication link of terminal feeders to supervision and control system is achieved using communication IEC60870-5-103 protocol, via optic fibers. Optical fibers from terminal feeders end in star couplers, connected by standard serial communication port with substation control computer (industrial PC).

In software for the control system, in substation control computer, we used existing subprogram solutions for local MMI as well as for link toward higher-level control center. Developed are new communication

subprograms (drivers) for transferring IEC messages. These are engineered using documentation of IEC60870-5-103 protocol, and specifically adjusted by consulting documentation of manufacturer of relays [1], [2] and [5]. List of IEC messages supported by terminal feeders is a part of user manual for terminal feeders [2] and we use the manual for selection of information and database programming.

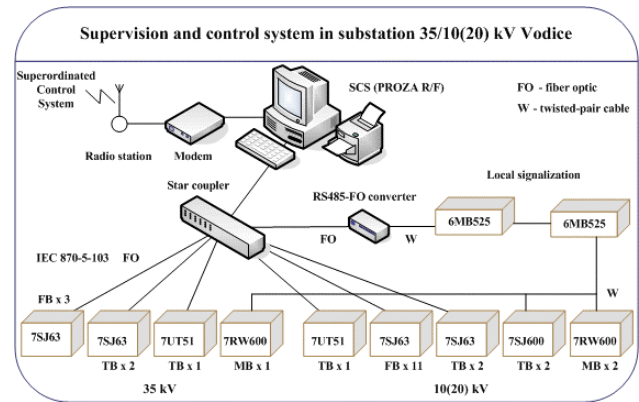


Figure 1. Overview of SCS in SS 35/10(20) kV Vodice

In numerical relays of generation SIPROTEC 4 [2], manufacturer dedicated a comprehensive attention to development of communication possibilities. Major communication protocols are supported in the range of information (protection, control, and signalization) which completely satisfied needs of end users for control system. Numerical relays feature two separate system communication ports, functional with an idea of independent data transfer to different requesting master systems. These two ports are separate and independent system communication interfaces for communication toward higher control center (SCS, IEC870-5-103 or some other) and the other for substation monitoring system and protection service. Application is supported by comprehensive technical documentation.

Substantial experience and “know-how” in programming and service of supervision and control system, helped that new control system was ready for installation and successfully put in service already in the first phase of reconstruction of substation.

2.2 SCS in MV SS 35/10(20) kV Kutina

In medium voltage substation 35/10(20) kV Kutina, substation control system was installed and put in service in 01/2004 (Fig. 2). Investor’s choice was installation of feeder terminals (ALSTOM P139 [3]), complying to requirements of relay protection in distribution utilities, as well as requirements on control, signalization and data transfer. Terminal feeders feature MMI with LED’s, graphical LCD and group of keys for local service. Relays have front for PC and two rear ports (COMM1, COMM2 system interface). Software package

MiCOM S1 supports access to terminal feeder and enables easily access to function settings using front port on the relay. Communication link of terminal feeders to supervision and control system is achieved using communication protocol IEC60870-5-103, via optic fibers. Optical fibers from terminal feeders end in star couplers, connected by standard serial communication port with substation control computer (industrial PC).

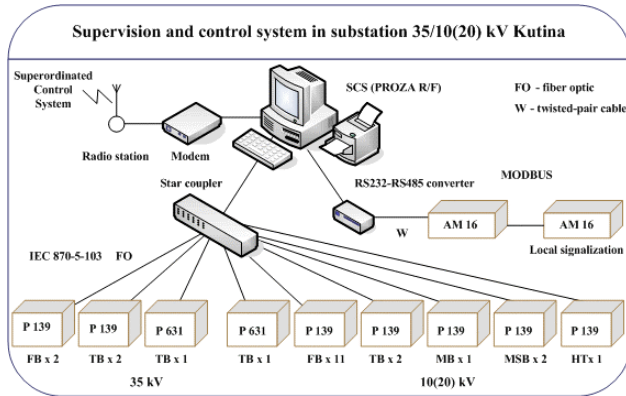


Figure 2. Overview of SCS in SS 35/10(20) kV Kutina

Two general-purpose alarm-signal units are used for local and alarm signalization. Alarm-signal units have communication subunit that feature MODBUS communication protocol, on RS485 copper wire link. These are connected to industrial computer via communication converter RS485/RS232. In software for the control system in control computer, we used existing program solutions for local MMI and for link toward higher control center. New communication subprograms for transferring of IEC and MODBUS messages are developed with help consulting information in documentation of IEC60870-5-103 and MODBUS protocol and specifically adjusted with using documentation of manufacturer of relays [1], [2] and [3].

The other communication programs within control computer cover for user MMI and data transfer toward higher control center. These programs interconnect with substation equipments and events, using named communication programs for IEC and MODBUS protocols. Industrial computer in regarding software, hardware and due to modular design is normally operating. Furthermore, open for expansion towards acceptance and transmission of data using new communication protocols as well as for acceptance and transmission of large quantity of information that is to be expected with more IED's in future. New control system was ready for installation and successfully put in service at the end of reconstruction of substation.

3. Conclusion

Communication protocol IEC60870-5-103 serves for data transfer needed in supervision and control system. It is

very well documented and simple in design and application. It is also in wide use and fairly supported by major manufacturers of numerical relays. When using modern feeder terminals as basic of supervision and control system, it is clear that most of the restrictions and weakness of named protocol are shown. Insufficiencies of the protocol and data that are specific within IED's of different manufacture can be solved by adjustments within the software subprograms of the control system. Most manufacturers lack of support within the protocol, fault data and disturbance records are solved by another communication interface for substation monitoring system.

Development of numerical relays along with modern trends in communication and computer technology asks for use of more powerful communication protocols. Unified numerical relays for control and protection are adjusted better to comprehensive scope of functions and data. Modern supervision and control system must have form of modular subprogram solutions. It makes possible simple adjustment, openness and extension in accordance with requirements of different numerical relays and manufacture. Hardware must be in major part standard. Described solutions for control system completely satisfy named requests.

Collaboration of manufacturers of numerical relays, on developing "stronger" communication protocol, resulted in making better protocol for relays, open to other numerical equipment installed in substation. Today, when the substations came to degree on which numerical relays of different manufacturer are connected on standard communication network of high throughput (Ethernet). Relays exchange standard messages and interlocking and have intercommunication with other relays or computers in network [6], with gained experience from practice and with comparing existing solutions. We can say that new standard IEC61850 will sure replace existing standard IEC60870-5-103. However, control system platform would be ready to adapt.

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