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Remote control of power system protection devices yesterday and now

***Abstract**. Paper presents examples of power system protections remote control together with their features and constructions. Described examples allow to see the slow change that appears in telecommunication links used in mentioned remote control systems over several years. Description of commonly used protocols and telecommunication standards is also included.*

***Streszczenie.** W artykule pokazano zasadę działania oraz przykłady układów zdalnego nadzoru urządzeń automatyki elektroenergetycznej jednego z producentów tego rodzaju układów. Pokazane przykłady pozwalają zaobserwować powolną zmianę, jaka dokonała się w połączeniach telekomunikacyjnych, używanych w tego rodzaju systemach, w przeciągu kilkunastu lat. W artykule pokazano również najczęściej wykorzystywane w istniejących rozwiązaniach protokoły i standardy telekomunikacyjne. (**Zdalny nadzór urządzeń automatyki elektroenergetycznej – wczoraj i dziś**)*

Keywords: remote control systems, power system protection, telecommunication standard, telecommunication link.
Słowa kluczowe: systemy zdalnego dostępu, zabezpieczenia elektroenergetyczne, standardy telekomunikacyjne,

Introduction

Nowadays the remote control of power system protection devices is a must [1]. The principal cause is the unceasing exchange of information between protection devices and primary apparatus of power system. Any changes in power network connections may result in protections settings modifications. Such situation may take place during fault occurring in any power system element, which has to be cleared through the opening action of the appropriate CB. More trivial situations may also lead to a certain modification, like in example earthing a line or isolation of any element for maintenance may need the modification of power system configuration. From the business point of view remote control of power devices may be also advantageous because it brings up substantial cost savings, reduction of mobilities to substations, reduction of the engineer number and eventually the payroll. In a short we can say that the greater the network get extended, the larger the number of possible disturbances is and the number of protection engineers to be enrolled is lower.

Such situation is more or less common in all developed countries with complicated high voltage (HV) networks composed of hundreds substations located in the area of many hundred thousand square kms.

Remote control systems of protection devices are presently used both in HV substations equipped with microprocessor-based control devices and MV substation devices. A few examples of HV remote control systems are presented in this paper.

Principle of operation of systems designed and produced in the second half of the 90's decade, to which telecommunication solutions of the first decade of the XXI century have applied in substations, are presented in this paper. Finally some information related to similarities in configuration (standards, ports and so on) are added.

Example 1 – data exchange system applied for protection devices of XX century's last decade

In the middle of 90's, most of HV protection devices were microprocessor type equipped with one or two telecommunication ports allowing exchange of data with SCADA and supervisory systems. Data exchange in those days was asynchronous and based mainly on RS232 and RS485 standards. Telecommunication links to protection devices were based on proprietary protocols developed by the protection manufacturer. Each protocol had different construction and features. First of all they were very simple but very error-sensitive. Remote connection between engineering staff office and substation was unreliable, based on old fashion telecommunication technology and very sensitive to electromagnetic influence.

Because of those reasons remote control of substation devices could be performed only via modem connection using asynchronous mode. Despite the problems with the transmission quality and unreliable transmission links, transmission errors can be effectively reduced so that the data exchange performance remains to be under control. Computers exchanging data, installed in both the power substation and in the office, are programmed in a certain manner to achieve this objective. Fig 1. depicts a set of telecommunication connections within the substation concerned.

In the Fig. 1, the example of telecommunication connections of described system within substation is presented.

It is worth to know that from time to time Ethernet links were also used for transmitting data in such systems. This concerns particularly the integration of digital fault recorder (DFR) devices. Those DFR devices could be accessed through concentrator telecom links usually allowing DFR files to be downloaded and analyzed. Additionally concentrator can run dedicated software allowing automatic data retrieving and archiving. Such functionality can be the step to archive the common platform to system of automatic collection of various records at the substation level. Such software can also organize transfer of DFR files to a regional or national centre after conversion to COMTRADE format and data pre-processing. Another important issue in case of those systems is the use of fiber optic connections for substation internal communication that makes the links very resistant to electromagnetic disturbances.

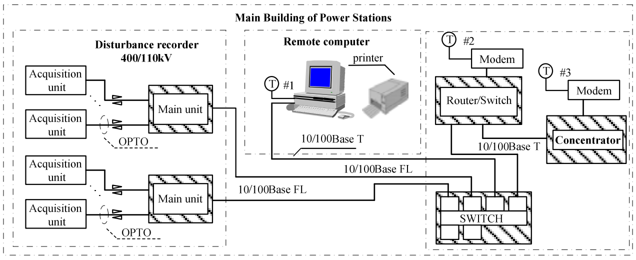

Fig.1. Devices and telecommunication links of protection devices remote control system as they were designed in the 90's

Asynchronous connections used for direct data transmission between substations and personal computers are based on PDH/SDH systems [3, 4]. Also such systems based on dial up routers, modem and simple LAN station LAN can be configured in such a way that the data transfer will be more reliable and resilient to different types of disturbances.

Optical switch plays a key role in older remote control systems. This telecommunication device divides one telecommunication link into a few of (for example 8) logically and physically separated links. The optical switch is able to swap the transmission standard from RS232 to optical 850nm or any other optical type. Combining similar switches together with appropriate telecommunications links allows for designing a telecommunication infrastructure, through which a secure and resilient to disturbance data exchange between power substation devices and a central substation computer (called data concentrator) can take place.

The infrastructure is totally dependent on the power substation configuration, and the structure of secondary side system which can be designed as centralized or decentralized.

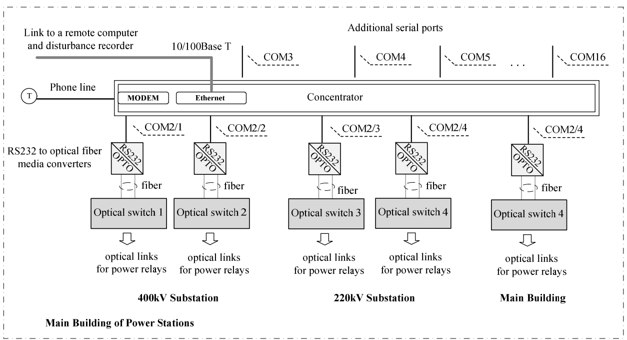

Fig. 2. Block diagram of telecom connections in substation with typical centralized remote control system

Both microprocessor protection devices and concentrator infrastructure are installed in the same building in case of centralized system. An example of such configuration is presented in Fig. 2. The structure of telecommunication structure is as follows: all links start at the concentrator COM port then connections are made from the COM port through optical fibers up to a particular protection device. Usually the length of optical fibers installed between devices does not exceed 100m, in such a situation a multimode fiber with 850nm light length transmitters/receivers can be used. In some rare cases where distance does not exceed 30m plastic fibers can be used instead of multimode ones.

Fig. 3 presents a distributed system, where the concentrator is located in the main building whereas protection devices are installed in other rooms called usually block-houses, spread all over the substation area. In such a configuration, data between concentrator and protection devices are transmitted by two sets of optical switches, easily recognized on Fig. 3. First level switches are installed near concentrator (usually in the same cabinet). They are used for directing data to the particular switch from second level, usually installed in the cabinet located in particular block-house. The switching of data paths is performed by each optical switch and consists of sending the special control block of data from concentrator to a defined switch, according to the algorithm and configuration implemented in the concentrator. The fiber connection used for data exchange between the main building and the block-houses can reach a few hundred meters, then in such a case only glass fibers can be used. The second level of data exchange is a composition of telecommunication links made between optical switches installed in block-houses and protection devices installed in the same small building. Usually the distance does not exceed 30m and then glass or plastic fibers can be used.

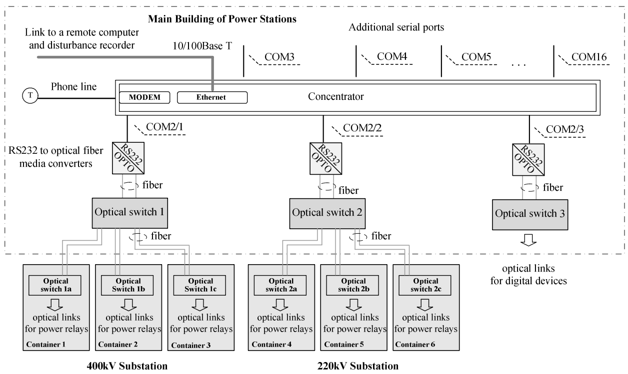

Fig. 3. Block diagram of telecom connections in substation in case of typical decentralized remote control system

It is worth noting that in the middle of 90's RS232 was the most common standard used for data exchange in protection devices. This standard has a major drawback, which is its excessive sensitivity to ubiquitous electromagnetic disturbances in power system substations. This leads to the appearance of huge errors in data transmission between concentrator and protection devices, which could be avoided only by using fiber optic links for the communications. This in turn makes impossible the change the protection settings. Such solution lead to the use of many fiber optic links from protections to RS232 converters installed near protection devices (installed either at the back of the same cabinet or in the form of special small module installed physically on DB9 or DB25 connectors). The use of fiber optic connections solves the problem of galvanic separation between protection devices and concentrator, which is a must in the installation of such remote control system.

There are many types of optical switches with many functions and features that can be used in the described system. Among them the most important are: number of ports, type of ports, supported protocols and quality of power supply. In the 90's, electrical RS232 was not the only standard supported by protection devices. A couple of them used electrical RS485 and optical connections based on 850nm light length fibers. Depending on the type of protection device port and its features the connection between the switch and the protection could be made in several forms.

If the protection has a port isolated from internal circuitry instead of fiber optic connections and dedicated converters, a port communication converter can be used. RS232 data can be translated directly into RS485 format as it is presented on Fig. 4. In such system one concentrator COM port is connected to the converter while on the other side a few protection devices are connected to the RS485 electrical bus. It is worth to mention that such solution had been used mainly in case of centralized station where distances between devices are quite small.

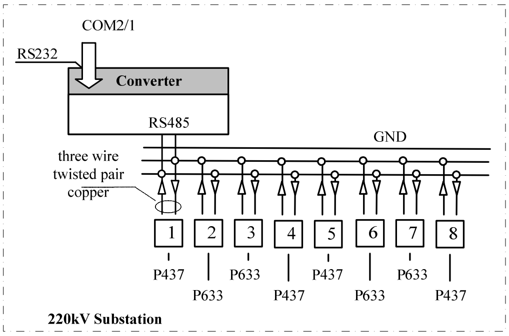

Fig. 4. Direct connection of concentrator to the RS485 bus with protection devices using single converter

However it is worth to remember that in case of couple of protection types the only particular converters should be used to archive correct and error free telecommunication link probably because their levels of optical signals are unique.

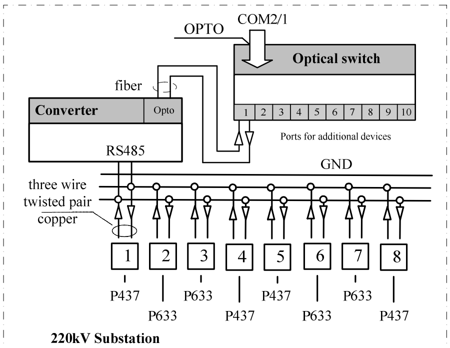

Fig. 5. Indirect connection of concentrator to the RS485 bus with protection devices using two telecommunication intermediate devices: optical switch and converter

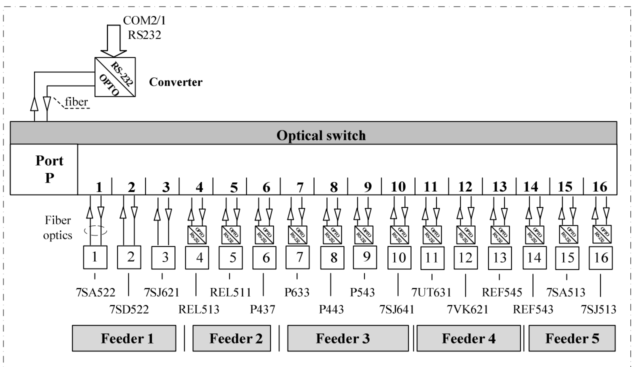

Fig. 6. Example of connections between protection devices and an optical switch

For higher distances (for example a few hundreds of meters) between the concentrator and protection devices the communication links can be solved as it is presented in Fig. 5. Such a solution is widely used. In this approach one channel of optical switch is connected to RS485 converter while other ports are used to connect to other protection devices equipped with other port types. Because optical switches had mainly optical ports, a conversion of data from this standard to another desired type e.g. RS232 is necessary. (serial communication ports are marked as COM2, COM3 etc. in most devices). The converter RS232/OPTO (RS232 to opto link) depicted in Fig. 6 usually is aimed to perform this task. It is also worth to mention that the same types of converters were usually used to connect optical switch ports with protection devices electrical ports (see converter no 4 on Fig. 6). Such ports were used in protection devices of ABB, Siemens, Areva (Alsthom) developed and installed in the 90's.

New protection devices produced at the beginning of 21st century are equipped with built-in optical ports. Direct connections can be established for data transmission to optical switch. An appropriate fiber optical cable equipped with the adequate mechanical connector (e.g. ST, SMA-B) is sufficient for the connection link.

This solution has been presented on Fig. 6, where ports 1, 2, 3 are connected to Siemens 7SA522 distance protection relay via direct fiber, while converters were used in other device connections.

Concentrator programs allowing the remote control of protection devices

In the 90's remote control of protection devices was performed as a main solution to a couple of problems appearing in telecommunication connections. They are, namely, errors of telecommunication links, lack of compatibility in data exchange between devices from different manufacturers, weakness and extreme sensitivity to data exchange errors of such protocols. Maintenance of the system becomes complicated and time-consuming because of frequent interventions both for repairing and replacing the hardware. Such limitation is quite easy to overcome by using very reliable links and dedicated programs for data exchange, especially when the installed hardware is from the same vendor. It is possible to establish such reliable links in a substation by using optical fibers, however some errors may be persistent in the data communication when connecting from the office with the concentrator using a PC.

One simple solution for this problem is the installation of concentrator data management software at the office and remote connection with the substation via a reliable link. On one hand one can gain a reliable, free of errors data transmission tool for data exchange between protection devices and maintenance engineers. On the other hand high connectivity of remote management system allows to work on the concentrator management desktop from the office PC. During the 90's telecommunication link between the concentrator and the office PS was based mainly on telephone lines through which the maximum speed of data exchange was around 33.6kb/s during extremely poor quality conditions. Such connection is presented on Fig. 7.

About 10 years ago LAN/WAN technology started to spread out in the electrical power industry. Nowadays it is used quite frequently for exchanging data between devices installed in substations and PC computers installed in offices. Remote control system of modern protection devices can handle such LAN/WAN telecommunication system without introducing any change in the protection principle of operation as can be seen in Fig. 8.

The only change that was made in the configuration of concentrator remote control management software is the use of Ethernet/IP connection instead of modem/dial up for desktop remote management. As has been mentioned before, in order to exchange data between the concentrator and protection devices, a special software from the protection manufacturer must be installed. This program should run automatically when required.

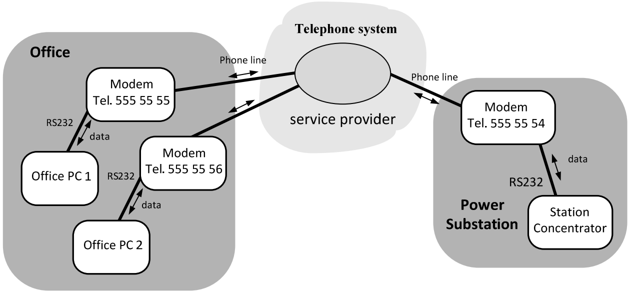

Fig. 7. Connection between station concentrator and office PC via telephone system – 90's up to 2006

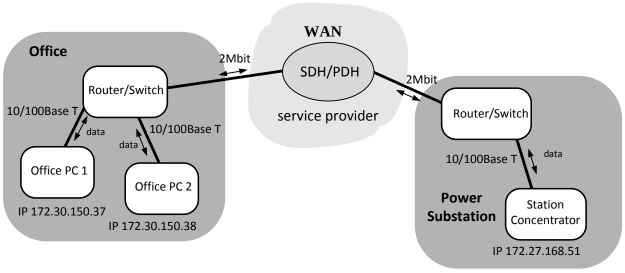

Fig. 8. Connection between station concentrator and office PC via WAN/LAN system [4]

The user's choice can be made on the computer desktop by clicking an option using the mouse or keyboard from the choice list, as it has been presented on Fig. 9.

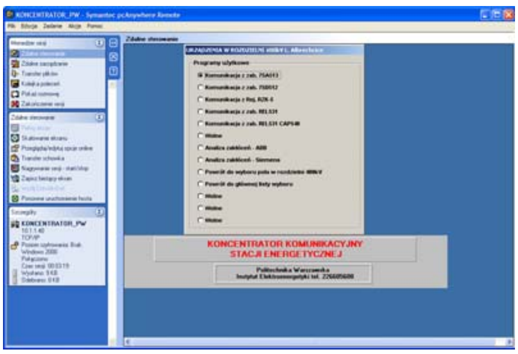

Fig. 9. Concentrator desktop seen by the user on the screen of office pc after connecting to the concentrator – the choice list of protections can bee seen

After the selection the concentrator sends a control packet to the optical switches establishing the path allowing data exchange from the computer to the particular protection device and runs the appropriate program. This program developed by appropriate manufacturer uses the created telecom link to exchange data with particular device allowing use of all its implemented features. Such approach allows the use of all programs made by particular company in the system of remote control despite the fact that those programs were developed for local or remote control. What is more telecom links are fully transparent for data exchange so there is no any problems with compatibility of data frames, data mapping etc.

Conclusions

As can be seen from the presented configurations, over the past several years telecommunication links within substation have change from asynchronous, using speed of several kb/s and vendors' proprietary protocols (ABB, Siemens, Areva etc.) to synchronous, using mainly 100 Mb/s Ethernet/IP common protocols. The same situation can be observed outside substation where modem links have been replaced by WAN/IP network. What is quite interesting regarding the remote control of different vendors power system protection devices, after a quite wide use of the common IEC61850 protocol [4] it is not possible to fully set up the configuration of devices without using a dedicated for this purpose program made by a specific vendor. This means that users are still forced to use different set up/maintenance programs from different manufacturers and then a concentrator is still required. Here a question arises - where is the compatibility which was and is one of the main arguments for the implementation of such complicated protocol which is IEC61850?

REFERENCES

[1] R. Obara, G. Kurpas, „Zdalna Komunikacja z urządzeniami automatyki zabezpieczeniowej - doświadczenia eksploatacyjne". Automatyka elektroenergetyczna nr 4/2006

[2] R. Kowalik, M. Januszewski: "Performance tests of power system protection, exchanging data through PDH network" (Testy działania urządzeń automatyki elektroenergetycznej wymieniających dane przez sieć PDH), PRZEGLĄD ELEKTROTECHNICZNY (Electrical Review), ISSN 0033-2097, NR 11/2008, Volume: 84, Issue:11, Pages: 20-26

[3] Ryszard Kowalik, Marcin Januszewski: "Tests of power system protections using SDH network" (Testy zabezpieczeń wykorzystujących sieci SDH) , PRZEGLĄD ELEKTROTECHNICZNY (Electrical Review), ISSN 0033-2097, NR 4/2009, Volume: 85, Issue: 4, Pages: 142-150

[4] R. Kowalik, M. Januszewski: "The example results of electrical power system protection devices interoperability tests using IEC 61850 standard", (Rezultaty przykładowych testów współdziałania urządzeń automatyki elektroenergetycznej wykorzystujących IEC61850), PRZEGLĄD ELEKTROTECHNICZNY (Electrical Review), ISSN 0033-2097, Nr 9/2008, Volume: 85, Issue: 9, Pages: 114-119.

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