OPTICAL FIBRE SOLUTIONS IN THE ROMANIAN TRANSMISSION GRID

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INTRODUCTION

Monitoring the own consumption in electric substation Domnesti can be considered as a closed application, independent from the modernisation of information transmission channels, or it can benefit of the upgrading plan and its implementation stage within the substation. Estimations are that the monitoring application for own consumption would be subsequently integrated into a SCADA application for tele-management, tele-control and monitoring of the substation equipment.

The solution would anyway benefit of optical fibres for signal transmission, while the conversion variants of useful information (powers, energies etc.) to be sent to the central processing point remain at the discretion of decision-making factors. Solutions already implemented in the country take into consideration the use of optical fibres dedicated to the SCADA application; taking into account the specific topic- monitoring a substation with a limited and well-defined area, the use of optical fibres is not foreseen for other services (communications). The use of optical fibre technologies within industrial automation networks and process control has been growing in the last decade. A basic optical fibre system using an optical reception and transmission circuit by means of an optical fibre environment provides many benefits that cannot be found with conventional systems using copper conductors:

- Great rate of data with big wave width
- Immunity to electromagnetic or radio interferences, as well as to the destructive impact of thunderbolts
- There are no closing loops of parasitic currents from the earthing circuits
- Reduced attenuation (therefore with no loss of data)
- Data transmission over great distances - 2 or 5 km by using Multimode optical fibres, or even more than 25 km for Single Mode optical fibre
- Small cable diameters that fit in almost anywhere, therefore they need only a little space
- Small weight

• No sparks occur if cut, therefore it is ideal for applications in dangerous environments
• There is no risk of electric shock
• Safe communications; • Flexible network topology
• Highly resistant to corrosive agents
• A longer lifecycle than copper or coaxial cables
• A low total cost of the system

Whenever the technology of data / signal transmission is selected, meant for industrial automation networks and industrial process control, consideration has to be given to the following difficulties met with cable utilisation:

• Inconvenient cabling- weight, laying, size, damping, interferences
• Distances between devices are quite small
• The great cable diameters take up a lot of room within cabling channels and pipes
• They require a different laying and distance against supply cables
• Low security
• Limited topology
• Costs can be higher than those for optical fibres

2. Standard IEC 61850

The solutions of automation processes rely on a great number of specifications or standards, which requires real time information integration, check, distribution and interpretation within the application from the data take over point up to the end-user, trader or natural person. The future power systems will face an increased demand for coherent information configurations describing the process data, automation devices and – if possible – the basic equipment.

Three standards have been defined with a view to meet the future requirements- **IEC61850, IEC61400-25** and **IEC61970.**

Power applications under such collection of standards have to provide the configuration of the system, protection and control equipment in a similar manner with supervision, control and data acquisition interfaces (SCADA) of control centres. Other applications that are already configured using such standards are:

- remote monitoring and error diagnosis,
- quality of energy,
- control and protection,
- monitoring the operational conditions;

Standard IEC61850 covers the "network communications within power systems and transformer substations" and is an element from the international standardisation for computerised models and data exchange for substations automation. **Standard IEC 61850** is basically meant to set up an open structure, as a communication standard within the automatic systems of substations. This standard intends to provide inter-operability of control and protection devices with the substation control system. The data from the high voltage equipment cross a hierarchical structure and are converted into digital form, then are sent to the control, protection and monitoring equipment using local networks. Intelligent electronic devices (IED) take the place of the electric-mechanical ones within conventional control systems.

3. Utilisation of SL7000 meters

Meters SL7000 have got RS232 and RS485 interfaces, with independent communication interfaces allowing simultaneous readings. Data in the SL7000 meter can be read using the standardised protocols IEC 61107 and DLMS/Cosem.

Since the protocols for SL7000 meters are standardised, the tele-management system can be further developed in the future using other equipment whose communication protocol is standardised or open.

The data reading network is complex of WAN type, and the physical support of data is optical fibre comprising equipment such as- routers, optical converters, Ethernet / RS485 converters.

There is physical insurance of data transmission:

- by supplying the equipment from uninterruptible sources UPS ;
- electrical cables of data transmission are shielded;
- software protection (routing protocols);
- by an application supervising the entire communication system, as shown in the figure below;

A software component is used in the report side viewing the Sybase- a ‚dynamic' database allowing the simultaneous access of several users. The hourly, daily and monthly consumption values are obtained by processing this database:

- by each supply line;
- by each substation;
- by bus bars;
- all the supervised installations;

This meter is the best solution for the up-to-date supervision of electric installations, moreover as it includes a communication protocol type XML and data can be easily seen from a distance. It can be used for distances not exceeding 1 km between gauges.

4. Taking over the information sent through secondary circuits from electric substations

The secondary circuit system has to be designed [9, 10] in such a manner as to comply with the requirements on:

- running, operation and maintenance;
- environment;
- seismic behaviour;
- electromagnetic compatibility;
- ergonomy;
- optimum profit – cost ratio;

The possibilities to comply with such requirements in case of communication support transfer onto optical fibre will be further considered.

Requirements for running, operation and maintenance

The design should provide the following running, operation and maintenance requirements under the specified performance values, such as:

- security of the personnel and of the operational functions (by observing the provisions of the norm ***PE 119 (Labour protection norms for activities into electric installations)*** and the installation and operation guidelines of equipment suppliers);
- execution rate (by selecting proper protection equipment);
- reliability / availability;
- easy manoeuvre (by a proper location of instruments that have to make manoeuvres at certain intervals and by implementing standard switching software to assist the operator with the manoeuvres and to avoid the wrong ones);
- easy maintenance (by providing access and maintenance corridors and by properly locating the components);
- easy repair (by using withdrawable modules located as to be easily accessible);
- without difficulty in obtaining spare parts (during the entire life of the system);
- easy testing at the operation site and self-diagnosis (by implementing logical testing procedures);

There is no incompatibility between the need to provide the specified functions and the communication environment with optical fibre. Moreover, the execution speed is further on exclusively determined by the selected protection / control equipment. The easiness of manoeuvre, maintenance and repair is much improved, as well as the implementation of self-diagnosis functions- that are already performed to other applications with optical fibre.

Environmental requirements

It is important to accurately know the environmental factors for both designers and suppliers, because different ambient conditions can impact nominal values and the performance of electric installations and equipment.

Climate is one of the impacting factors over the the performance of electric equipment, therefore it the the main physical and chemical condition of the atmosphere, both for open air installations and for indoor ones. Daily seasonal modifications are also included within climate. It includes both natural factors such as air pressure, temperature, temperature variations, humidity etc. and pollution outcomes such as- air pollution by dust, salts and gas.

STAS (standard of state) 6535-83 (Climatic division of the land for technical purposes) and *DIN 50010* & *DIN 50019* provide information on the climatic division of the earth. Tentative information on the climatic conditions of our country are provided in *PE 101(Norm for building electric connection and transformer installations over 1 kV)*.

Additional climatic factors include- altitude, temperature variations, external and internal heat, rain, storm, winds (regulated under *STAS 5325 (Normal protection degrees by means of casings. Classification and testing methods)* regarding the protection degree against water and dust getting into outer cabinets and boxes) and air pollution.

Additional environmental factors refer to- bad soil conditions that can lead to improper earthing resistance values (regulated under *STAS 12604 – Protection to electric shocks*); biological consequences through the fauna (small animals like rats, mice, termites, birds, reptiles that produce the most significant failures- shortcircuits) and the flora (mould and fungi).

Complying with the environmental requirements is the first benefit of optical fibres, including of the additional modules adapting the information for such transmission medium.

Location in seismic zones

The components of secondary circuits have to guarantee a proper operation during and after the earthquake. The characteristics of probable earthquakes in a certain area can be obtained by recording seism in the past. There are maps of seismic areas nowadays for all regions, with Romania's macro-zones given in ***SR 11100/1-93***

(Seismic zoning. Macro-zoning Romania's territory). The components or systems of a substation are divided in two categories in seismic terms - class A, including devices whose failure do not influence the proper operation of the substation during or after the earthquake, and class B, including devices that prevent the substation operation during or after the design seism (defined in *PE 148 – Guidelines on the general conditions of anti-seismic design of technical installations in electric substations*).

Electromagnetic compatibility

Electromagnetic interferences because of the various disturbance sources in air insulated (AIS) or in gas insulated (GIS) substations can lead to unexpected drives or even to equipment deterioration. The problems relating to electromagnetic compatibility can be classified in three groups:

- defining the level of transient over-voltage to the terminals of secondary equipment;
- defining the equipment capacity to withstand and drawing up testing recommendations;
- elaborating recommendations for the whole installation of secondary circuits, including the earthing plant, with a view to cut down transient over-voltages (surges) impacting secondary equipment;

Disturbance sources in electric substations are- switching into primary circuits in the high voltage part; atmospheric surges; HV tests made within the substation; groundings; switching into secondary circuits; electrostatic discharges; radio emitters (transmission-reception stations, mobile phones etc.). Such disturbance sources can propagate by direct coupling or by the waves they radiate, only the high frequency ones- MHz.

The most important measures reducing the outcomes of electromagnetic disturbances are:

a) Proper design and testing of secondary equipment in terms of frequency amplitude and energy of disturbance in order to provide the guaranteed immunity level;

b) Proper construction of (current and voltage) transformers; actual shielding between the primary and secondary windings, testing the behaviour to high frequency;

c) Exclusive use of shielded cables for secondary circuits, and if required even cables with specially designed shields; earthing at both ends is generally beneficial;

d) Including earthing cables within channels and ditches in parallel to the conductors, in order to cut down currents through the shield and to inductively couple the secondary circuit to the earthing system;

e) Additional recommendations for gas insulated substations:

- connecting the reinforcing bar of reinforced concrete to the earthing system in various points, especially in the floor;
- providing a good shielding to the SIG bushings – air through multiple envelope connections and wall (bar, metallic wall) and multiple additional connections between the wall and the earthing network, as well as between such network and ground;
- galvanic connections between the HV cable shields and SIG envelope; if the shield earthing is allowed only in a single point, the other end is left free;
- **Ergonomic requirements**
- The information shown on the screen has to be limited in order to maintain a reasonable supervision quality. To this effect, the screen filling degree should not exceed 6%. However, the system outlook and location has to be adapted to human capabilities in order to carry out the ergonomic requirements. To this end:
- information on the displays or screens has to be visible (legible) and classified in a logical manner (graphics, colour);
- screens, displays and/or control panels have to be arranged so as to allow the operator a comfortable area of activity;
- a fast response system is required when an operation has been made;
- there has to be a proper environment (light, temperature, humidity);

Economic considerations

The following items have to be taken into consideration in order to obtain the cost of the entire lifecycle of secondary circuits:

- cost of initial investment;
- commissioning cost;
- cost of operation, maintenance and repair;
- cost of personnel training
- cost of later system extension and/or modernisation;

A standard architecture is recommended for the new (conventional and digital) secondary circuits, with details specifications for various functions, for all important system parameters and for interfaces. Such mode of operation provides the following benefits:

- less engineering for substation design;
- CAD use;
- shorter installation and commissioning times;
- easier maintenance, repair and extension;

- storing a smaller amount of spare parts;
- a better control of system costs;

The software and its benefit to be adapted to the user's requirements are not easy to estimate; there is dependence on such requirements when the integration degree is high. The best way to get an acceptable software cost is to use software containing standardised programme modules. In case of application software, recommendations are to use applications that can be easily configured for each installation individually, with no need of re-designing.

5. Functions of the secondary circuit system

The secondary circuit system carries out [4] the following categories of functions:

- protection;
- automation;
- control (operation, switching, blocking);
- supervision (metering, signalling, registration);
- autosupervision;
- exchange of information between substations and users;
- auxiliary dc and ac supply;
- air conditioning;

Such groups of functions can be considered as provided under sub-systems. All sub-systems include the required cabling and connections.

The functions of the secondary circuit system are not (compulsorily) associated in physical terms to distinct pieces of equipment.

6. Required performance of the secondary circuit system

The performance of such systems refers to availability (a mixture of reliability and maintainability).

Availability is defined as a ratio between the mean time of good operation (MTBF) and total time, that is $A = \frac{MTBF}{MTBF + MTTR}$, where MTTR is the mean of repair time. Availability depends on- concept, design, construction and commissioning, equipment / hardware and software components quality, object and type of redundancy, maintenance and auto-supervision, resistance to particularly severe tests, protection against electromagnetic disturbances, environmental conditions.

Reliability (safety, security) cab be improved by doubling or even tripling the functions / critical equipment thus making redundancy. Additional functions (equipment) can be active (operating uninterruptedly) or passive (in 'cold' reserve, automatically or manually driven).

Redundancy (providing inter-operability even in case of malfunctions) is an option that has to be decided upon during design, depending on the required reliability and on the economic terms (profit / costs ratio). Several kinds of redundancy can be applied- parallel, serial, serial-parallel.

A significant reliability increase is obtained by introducing equipment with automatic supervision functions, which is very important especially for the protection equipment.

Auto-supervision (automatic monitoring, testing) is relatively easy to obtain by using digital techniques (computerisation). Thus personnel intervention is possible shortly after a damage, which can be effectively remedied; when auto-supervision is absent, damages are discovered only upon the periodical (maintenance) checks and tests or after some failure.

The parallel connection of two units / components has to be made in such a manner as to have the two units / components fully separated, independent in constructive terms for inlet circuits, execution, operational supply and transmission paths. The serial connection does not always require the full separation of the units / components.

Parallel redundancy is used more often than the serial one.

The primary process determines the reliability and safety degree of secondary systems. The wrong active or passive operation is restricting the reliability or safety. The wrong operation of secondary circuits leading to dangerous conditions impacts the safety. The wrong operation of secondary circuits with only harmful effects is not dangerous but is limiting the availability. Redundant systems are indispensable in order to get the required operational safety or / and security against wrong operation. Such systems have to comply with the following conditions- components or system parts failure must not impact safety, components or system parts failure must not limit availability.

CONCLUSION

Control, supervision and protection systems are closely inter-connected within a substation. The protection system has to prevent and restrict failures of primary equipment and to protect the stability of the power system.

It is a fundamental component of the substation and its part is to disconnect as quickly as possible only the faulty circuits (10-50 ms, excluding the CB own time). The protection function can be also performed differently depending on the protected object, on the available protection equipment and on the user. The benefits are as follows- the circuits of other functions are not compromised; it operates uninterruptedly with higher performance; it tolerate defects both at bay level and at substation level; the protection function is continuous, even if total communication is lost.
Protection sub-systems have to communicate well to the control/supervision ones in order to provide data on the operation, faulty phase and settings.

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