IEC 61850 STANDARD – A NEW STEP IN THE FUTURE OF THE COMMUNICATION PROTOCOLS

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Apariția standardului de comunicație IEC 61850 deschide noi perspective de evoluție a sistemelor de comandă control din stațiile electrice deoarece integrarea echipamentelor existente şi a celor de ultimaă generație de la diferiti furnizori poate fi acum posibilă. În opinia autorilor reprezintă contribuție personală prezentarea modului în care acest standard a evoluat, a avantajelor certe pe care le oferă precum şi a perspectivelor ce rezultă ca urmare a dezvoltării comunicației pentru sistemele de protecție comandă control. În lucrare au fost prezentate noile protocoale de achiziție şi comunicație în stațiile electrice precum şi tendințele de dezvoltare. De asemenea autorii au insistat pe avantajele adoptării unitare a standardului IEC 61850 la nivelul Sistemului Energetic Național, luând în considerare condițiile implementării tot mai frecvente în stațiile electrice a sistemelor moderne de protectie şi comandă control.

The appearance of the IEC 61850 communication standard open new perspectives for evolution of the protection and control systems from electrical substations because the integration of existing equipment with the latest generation equipment from different manufacturers can be possible now. In the authors opinion, represent a personal contribution presenting of way, which this standard evaluated, the clear advantages which offer and the perspectives which result following of the communication developing for protection and control systems. In the paper was presented the new protocols for data acquisition and communication. Also the authors insisted on the advantages for IEC 61850 unitary adopting at National Power Grid level, taking in consideration frequent implementation of protection and control system in the electrical substations.

Keywords: IEC 61850**,** communication protocols**,** protections and control systems, IEDs (Intelligent Electronic Devices), SCL (Substation Configuration description Language), GOOSE (Generic Object Oriented Substation Event)

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1. Introduction

Usually substation automation systems including protection are using proprietary communication systems which are special developed by manufactures. The dependency from single suppliers restricts the developing of the networks and also the innovative competition because it forces the utilities to follow the pre-defined system configurations of these suppliers independent if these are optimized for the user. The general idea of standardization for communication protocols between IEDs (Intelligent Electronic Devices) is to overcome all these limits and to bring a long lifetime safeguarding the investments of the utilities.
Many protocols are presently available for communications in substations. It is common to find substation automation systems running on different protocols, from different manufacturers, in a substation. Substantial efforts are needed on engineering and maintenance in order to enable systems running on different protocols to exchange information.

2. Actual situation

High-speed network communications have already changed the world we live in and are poised to bring significant changes to the way we control and operate the power system. To be successful, new technology requires industry-wide agreement on diverse topics such as system architecture, communications infrastructure, data models, and high layer protocols. This agreement is being achieved through industry standards with IEC 61850 and IEEE C37 series have taking the lead role.

There has been a world-wide initiative to have one single communication standard for the whole world. Experts from many continents, such as Europe, America, have worked together and produced IEC 61850, an international standard which addresses the interoperability of and the life-cycle support for substation automation equipment in substations.

The standard IEC61850 “Communication Networks and Systems in Substations” supports all communication for substation tasks like control, protection and monitoring and covers communication between IEDs from the process level (data acquisition, sensors and actuators) over the bay level (protection, monitoring and control tasks) up to the station level.

The present substation automation market is characterized by manufacturer-specific and hardware-oriented solutions. A large number of protocols for communication exist giving rise to the problem that equipment from different manufacturers cannot communicate with each other, or only with disproportionate expenditure.

Manufacturers have a long experience with the changing of technological environment in the substation automation systems field where the new equipment are developed, produced and maintained. When a utility acquires an entire automation system from a single manufacturer, the system is generally optimally configured to avoid problems on protocols. However, if the system comprises equipment from different manufacturers, the utility could encounter incompatible protocols and would need additional resources to deal with them.

Today a substation automation system comprises three hierarchical levels, i.e. the station level, the bay level, the process level, as shown in Fig.1. The communication between station level and bay level is sometimes realised by means of different incompatible protocols such as IEC 60870, Profibus, DNP, LON, Modbus, MMS and hundreds of other proprietary and non-proprietary ones.[1]

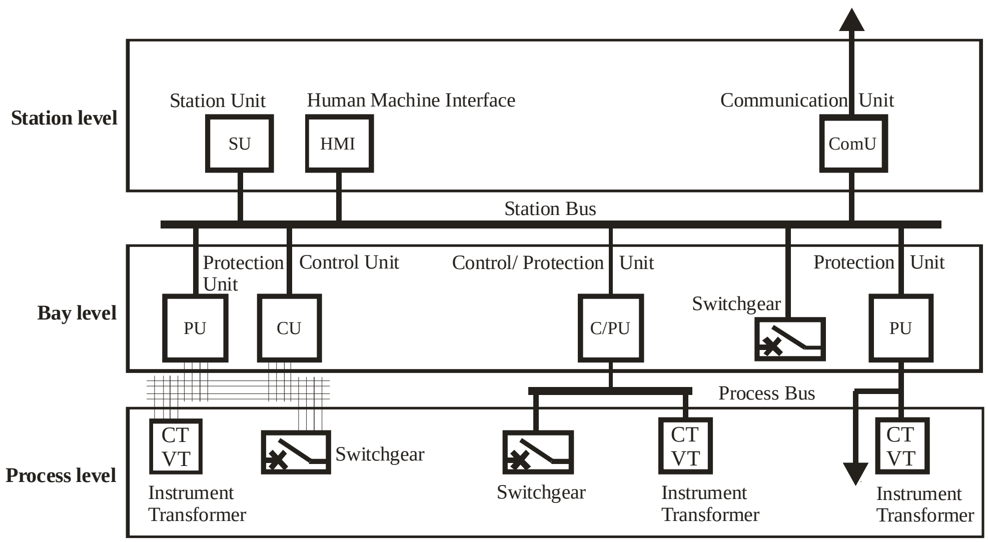

Fig. 1. The hierarchical levels in the actual substation automation systems

Parallel wiring is mostly used for the communication between the bay level and the process level. In some countries, only two levels, the station level and the process level, are employed. In this case, the components of a substation control system are connected via a station bus and the process is connected to the components via parallel wiring.

Gateways, or protocol converters, largely solve the problem of incompatibility between protocols, but they add extra equipment to the system. They also introduce delays and possibly errors in the communication paths.

Even in situations where gateways are not used, the large number of protocols is undesirable from the point of view of both the users and the manufacturers. In a utility, personnel need to be trained to handle all the protocols. Utilities also engage themselves more and more internationally nowadays, often acting as consultants to utilities overseas. To them, fewer protocols would be desirable. For manufacturers, tremendous sales, marketing and development efforts are also required to deal with a wide variety of protocols. Such efforts would eventually take the form of costs passed on to the customers.

A reduction in the number of protocols is extremely beneficial for both the manufacturers and the users. Standardization is the key for the advancement of the connectivity and interoperability of systems. Through standardization both the users and the suppliers can arrive at economical and reliable solutions.

Applications and communication equipment have different technology lifetimes and are stable over a long time, but the communication technology trend in the last twenty years was changed. When the communication technology changes the communication part of the automation system should be forward compatible to the new technology. If not, the utility would need to upgrade only the communication part of the automation system. The communication technology such as Ethernet must provide the best compatibility to forthcoming systems.

The lifespan of a substation is longer than that of the substation automation system.

The standard must provide tools for updating, extending, testing and maintaining the substation automation system and its communication system, over the lifetime of the substation at the least. The tools must be capable of handling equipment from different manufacturers. [1]

3. IEC 61850 origin

In the early 1990s, parallel activities were taking part in Europe and in the USA. The IEC identified the need for a standard interface to the new "protection Intelligent Electronic Devices (IEDs)" that were emanating from the different manufacturers. IEC TC57 and IEC TC95 set up a joint working group which developed a standard for the "Informative interface of protection equipment" (T103). In the USA, a project called “Utility Communications Architecture” (UCA) was carried out by the Electric Power Research Institute (EPRI) to develop a common infrastructure for real-time utility communications across the utility enterprise. The first standard resulting from the UCA effort was published in 1996 as IEC 60870-6 TASE.2 (ICCP) and is used for inter-control-centre communications. The part of the work on the communications within a substation became UCA 2.0. In 1995 the IEC recognized the need for a more general standard covering communications networks and systems in substations, and set up new working groups TC57 WG10, WG11 and WG12 (Technical Committee, Working Group) to develop this standard series. These three working groups brought together experts from many countries – with experiences of both the IEC 60870 series of protocols and UCA 2.0.

It soon became obvious that the three IEC working groups were developing the IEC 61850 standard at the same time when EPRI was developing the UCA 2.0 definitions. In order for UCA 2.0 to reach a wider audience, EPRI planned to have the documents published by the IEEE [2]. To prevent these two definitions of substation communication from competing against each other on the world market, it was concluded that the activities of IEC and EPRI would be harmonized to arrive at only one world-wide-accepted standard, which is IEC 61850.

4. General description of the standard

IEC 61850 is based on a common application model of substation automation functions. It defines a set of standard interfaces through which data flow. These interfaces are called logical nodes, and a logical node is like a window of a function to the outside world.

4.1 Logical nodes

IEC 61850 is based on a common application model of substation automation functions. It defines a set of standard interfaces through which data flow. These interfaces are called logical nodes, and a logical node is like a window of a function to the outside world. The term ‘logical node’ may sound highly technical, but in fact it is quite simple. In a power network, bus bars are called nodes because power flows between them. According to IEC 61850, data flow between the interfaces and hence the term ‘node’ is used. ‘Logical’ signifies that the interface is not physical one but rather a conceptual one.

Allocating the Logical Nodes allows free allocation of functions to devices and levels. The standardized logical node and data object naming provides the semantics for substation automation, and assures interoperability also on application level.

The users expect ‘gateway-free’ access to all intelligent components of the substation automation system by means of the commercially available tools and standard communication protocols. These requirements demand a flexible bus at all levels.

The use of Ethernet technology fulfils these requirements and provides a uniform access to the data throughout the whole substation. Ethernet is the only computer communication system whose present version is compatible to its original version invented in the 1970s.

4.1 Substation configuration description language

IEC 61850 defines also the Substation Configuration description Language which allows the configuration of an automation system to be defined and the settings of IEDs from different manufacturers to be fixed by the user or any of the manufacturers involved.

Substation configuration language (SCL) files were created within the IEC 61850 standard as a means to standardize the method of describing communications capabilities within IEDs. Initially it was thought that these SCL files would be best collected directly from the IEDs, essentially a self-description method. However, it was quickly realized that system designers rarely have each specific IED at their disposal during the settings implementation phase. Designers work at their desks while the IEDs are at the panel shop or substation. Therefore, SCL files are distributed via a combination of electronic storage and email as well as directly from the IED. [4]

Due to its unique features to describe in separate sections substation switchgear, the functionality attached to it in terms of logical nodes, the grouping of logical nodes on physical devices (IEDs), and the communication connections between the IEDs, this language is also an excellent tool to handle the flexibility in a very efficient way.

4.3 Classification

IEC 61850 comprises 14 parts. The development of IEC 61850 has been demanding and has taken into consideration the inputs of experts from different countries and with different experience. The 14 parts find themselves in five groups namely:

- System Aspects
- Configuration
- Data and Service Models
- Mapping to real communication networks
- Testing

4.4 Advantages of the new standard IEC 61850

IEC 61850 is the only standard which covers the communications in all the three levels of equipment in a substation, namely Station Level, Bay Level and Process Level. Other standards cover the communications in only one or two of these three levels because most standards were developed for specific purposes.
IEC 61850 advocates the Ethernet instead of master-slave communication. The advantages are:

- In Ethernet, a device can send a message whenever it wants, and there is no master device governing which device can talk at any given time. However, a master device is essential in master-slave communication. It can be a bottleneck because when it fails, other devices cannot communicate.
- Multicasting (i.e. one device sending a message simultaneously to several devices) is simple in Ethernet and improves the performance of time-critical messages. TCP/IP is the transmission protocol of the Internet. IEC 61850 facilitates data transfer through public or private data networks by specifying protocols compatible with TCP/IP. Data of other protocols based on Ethernet and TCP/IP, such as web-service data for remote maintenance, can be transmitted in parallel via the same communication infrastructure.
- All IEDs compliant with IEC 61850 are interoperable, and no gateways are required.[1]

5. IEC 61850 interoperability projects

5.1 Interoperability 'Bay Devices and Station Controller', Germany, 2000

The German project Open Communication in Substations (OCIS) started in January 1998 and was finished in November 2000. Project partners were three manufacturers, ABB, ALSTOM and Siemens, the German utility VEW (now REW) and the Research Institute FGH in charge of the management of the project and the testing work. The project was completed and concluded in a conference in November 2000. The goals of the project OCIS were to:

- Assist with the standardisation process to reach one world-wide standard IEC 61850
- Assist with the harmonisation process between IEC 61850 and UCA 2.0
- Test and compare IEC 61850 and UCA 2.0 drafts with respect to feasibility, applicability and efficiency
- Test the independence of communication stacks and applications in IEC 61850
- Test the interoperability given by the standard.

There were two test set-ups, one with Profibus-FMS and the other with MMS/Ethernet (see Fig. 2.). The first test set-up was built with Profibus-FMS as the station bus, consisting of a station unit developed by one manufacturer and three combined protection and control devices developed by the three different manufacturers. The second test set-up was composed of MMS/Ethernet as the station bus, with a station unit developed by one manufacturer and again three combined protection and control devices developed by the three manufacturers.[3]

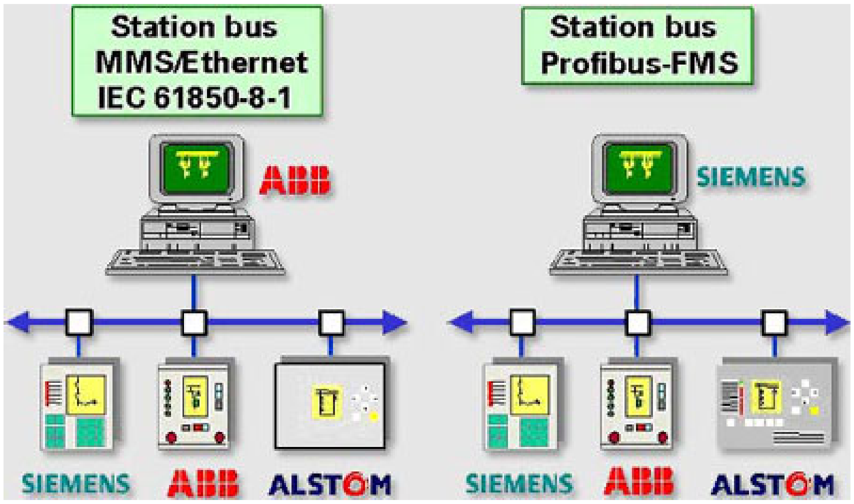

Fig. 2. Test set-ups with Profibus-FMS and with MMS/Ethernet

5.2 Interoperability 'Between Bay Devices', Canada, 2001

To support and speed up the standardisation work on the transfer of digital data according to IEC 61850 Part 8-1 between the process level and the bay level, or between bay devices, ABB and Siemens arranged a trial test on the required equipment. In this project, the engineering carried out together by the different manufacturers was also tested. The objectives were to:

- Verify the concepts of the IEC enhanced GOOSE (Generic Object Oriented Substation Event).

On the occurrence of any change of state, an IED will multicast a high speed, binary object, Generic Object Oriented Substation Event (GOOSE) report by exception, typically containing the double command state of each of its status inputs, starters, output elements and relays, actual and virtual. A GOOSE report enables high speed trip signals to be issued with a high probability of delivery.

- Test the basic concepts of Substation Configuration Language
- Demonstrate interoperability of devices from different manufacturers
- Demonstrate that devices from different manufacturers can be configured to perform the required control and protection functions.

The test set-up is shown in the Fig. 3. There were several demo cases. Dependent on the demo cases the devices were configured by the engineering files based on IEC 61850-6. In one case a short circuit was simulated by the Omicron Test Equipment and the corresponding current was fed into the Siemens protection relay. The relay issued a trip signal to the ABB Switchgear Simulator. The simulated circuit breaker opened and sent a GOOSE message 'Position Open' to all other devices. The ABB device, which was configured as Auto-reclosing relay, acted to reclose the circuit breaker. All events were recorded by the OMICRON Test Equipment in usual way. The demonstration was successful and the North American UCA-specialists were convinced of the prospect of IEC 61850. Thus UCA presented the so-called GOOSE-Award to the manufacturers ABB and Siemens.[3]

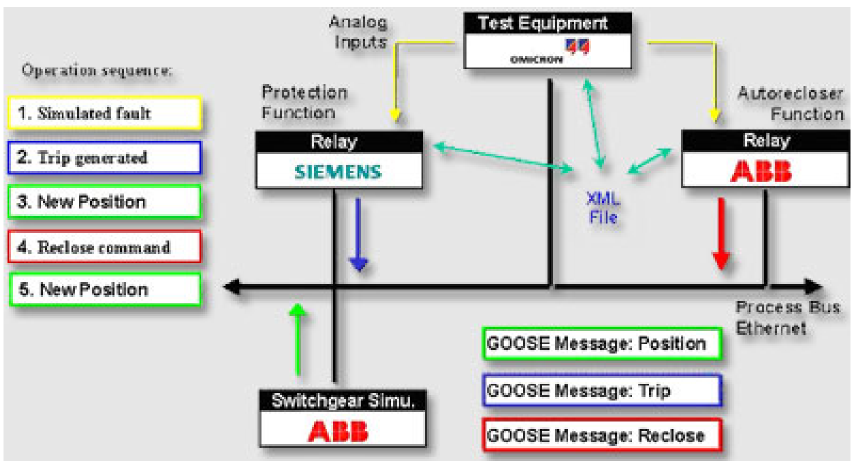

Fig. 3. Interoperability between bay devices – Test set-up

5.3 Interoperability 'Sampled Values', USA, 2002

In January 2002, again at the UCA Utility Initiative Meeting in Danapoint/USA, the second main interoperability demonstration was performed. The objectives were to

- Demonstrate the interoperability between non-conventional sensors, protection relays and revenue meters achieved with IEC 61850-9
- Develop the first prototype devices supporting IEC 61850-9.

The demo set-up is shown in the Fig. 4. The equipment was connected in a point-to-point manner. The demonstration was again successful at the homeland of UCA. Prior to Danapoint, the common support from Siemens and ABB for IEC 61850-9 was announced at CIGRE 2000 meeting. Type conformance tests were carried out at KEMA in November, 2001 and the corresponding type test certificate awarded to the two companies.

Similar configurations were also presented at the Hanover Fair in April 2002 and at the Omicron Users' Meeting in Lindau in June 2002.[3]

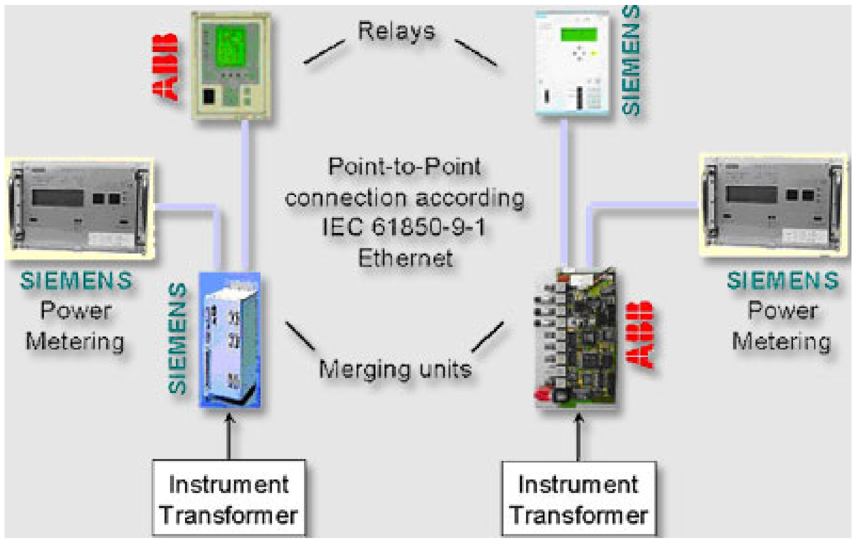

Fig. 4. Demonstration test set-up

5.4 Interoperability 'Trips and Sampled Values', USA, 2002

In September 2002, at the meeting of the UCA® International Users Group in Ponte Vedra, Siemens and ABB worked together to demonstrate the interoperability of GOOSE messages and sampled values, both being simultaneously transmitted via over the same communication bus. The demo set-up is shown in the Fig. 5. The Omicron Test Equipment simulated a short circuit and issued the corresponding high current to the sensor simulation. The sensor simulation converted continuously the analogue signals into sampled values and put them on the bus. The Siemens protection relay received the sampled values from the Ethernet network, detected the short circuit and sent a trip signal to the ABB Switchgear Simulator. The Switchgear Simulator opened the circuit breaker. The opening signal was transmitted again in the form of a GOOSE message to all the equipment on the communication network. The ABB auto-recloser received this message and issued a reclosing command to the Switchgear Simulator. This demonstration using real applications was regarded by the participants as very successful.[3]

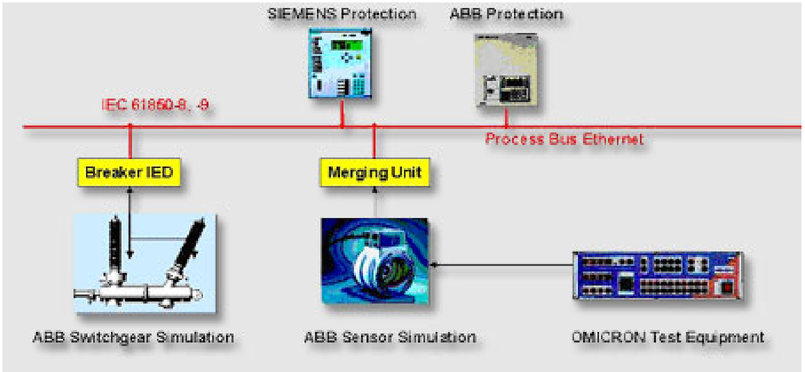

Fig. 5.Test set-up for interoperability 'Trips and Sampled Values'

5.5 Interoperability 'Between Bay Devices' further projects 2002-2004

A test series was performed in Berlin at the end of 2002 combining protection devices from ABB, ALSTOM and Siemens in the test configuration shown in Fig. 6. Unlike earlier test series, this interoperability test series was conducted equivalent real-life situation including in particular degraded and unfavourable ones to prove selectivity, security and quality. Engineering on the devices of the three manufacturers was done using the Substation Configuration Language (SCL) via e-mail, as shown in Fig. 7.

The test was very successful. It proved interoperability and the possibility of easy engineering. The vendors met in Berlin plugged their devices together and immediately the system started running. This suggests fast installation and commissioning due to vendor independent engineering data exchange based on IEC 61850-6.

Out of the total of 39 different test cases 35 passed without any problems. Only two cases showed minor implementation errors, whilst two revealed an ambiguity in the standard. One of the key objectives was to check the standard's validity. This was fulfilled, and the experience gained could be used immediately to improve the specification and thus prevent problems in the future. [3]

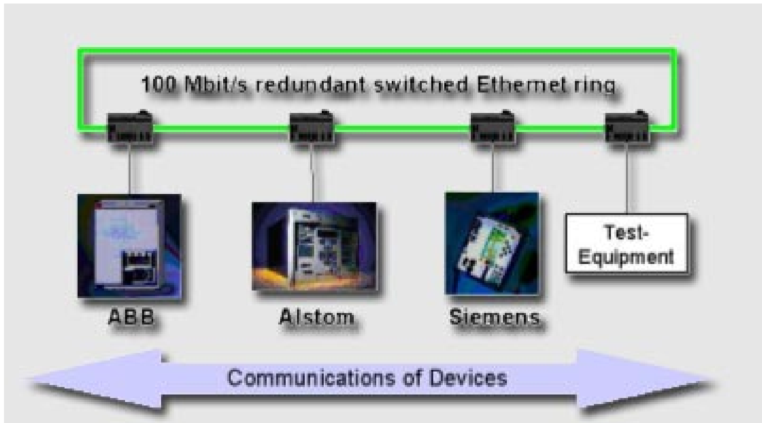

Fig. 6. Project test configuration

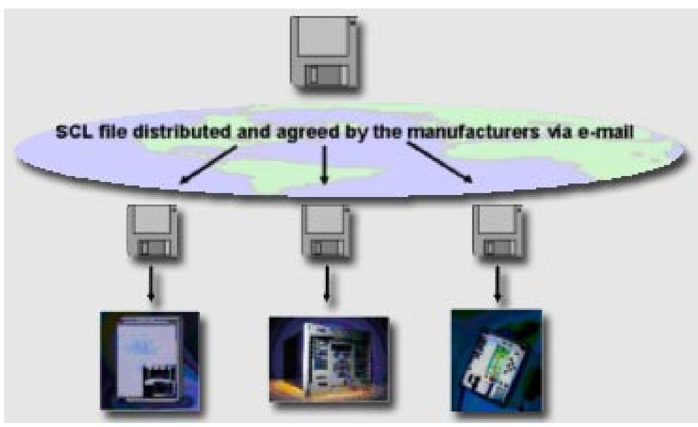

Fig. 7. Substation Configuration Language (SCL) - Engineering on the devices via e-mail

5.6 UCA® International Showcase at IEEE/PES Substations Committee Annual Meeting in Sun Valley, USA, 2003

The IEEE Power Engineering Society Substation Committee met in April 2003 in Sun Valley, Idaho, USA. UCA® International organised a six-hour demonstration session in which manufacturers displayed their latest work on IEC 61850. Based on the earlier interoperability test in Berlin, ABB, ALSTOM and Siemens showed the transmission of trip signals over Ethernet using GOOSE messages.

The subject of the demonstration was an inter-tripping function. It was the emulation of an equivalent real-life situation consisting of three circuit breakers, each designated to a protection device of one of the vendors. The devices were connected via an Ethernet network and the communication was according to IEC 61850. The Omicron Test Equipment simulated a short circuit and the current was fed into the Siemens relay. The Siemens relay issued a local trip to its circuit breaker and at the same time sent a multicast (one message and multiple receivers) GOOSE message over the Ethernet to the ABB relay and the ALSTOM relay to initiate inter-tripping. The ABB relay and ALSTOM relay independently received the GOOSE message and each generated a local trip. The three local trips were indicated by the respective flashlights (see Fig. 8.). The figure shows the layout of the demonstration. [3]

Fig. 8. Different equipment in operation **IEEE/PES Substations Committee Annual Meeting in Sun Valley, USA, 2003**

The use of Ethernet communications for all the substation automation functions means standard and simpler cabling in comparison with the use of parallel communications. This is an advantage in project execution, equipment installation and equipment testing.

6. Conclusions

The standard IEC 61850 introduces a strict separation between application and communication functions and fulfills all needs from high speed real time data transmission up to event logging and monitoring systems. This allows implementing in the same protocol on low cost communication equipment as well as on more costly high performance communication equipment. Therefore in the substation the existing control and protection equipment (relays, RTUs) can be connected with new generation of devices from different manufactures without any converters for communication protocols. Interoperability of IEDs from different manufacturers and the elimination of gateways is the major advantage of IEC 61850.

IEC 61850 is now released to the industry. Ten parts of the standard are now International Standards (part 10 is a draft international standard). This standard addresses most of the issues that migration to the digital world entails, especially, standardization of data names, creation of a comprehensive set of services, implementation over standard protocols and hardware, and definition of a process bus.

For the National Power Grid, the integration of this standard will be a new developing level which will allow data communications between existing equipment and new implemented equipment. IEC 61850 will bring a time and cost saving since the absence of gateways means less equipment, no unnecessary delays and no additional errors caused by protocol conversions. This new standard will open for actual Romanian Power Grid, new possibilities for developing of the intelligent and remote control substations which will allow quality and safety interconnections with European Power Grid.

R E F E R E N C E S

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