Paper accepted for presentation at 2009 IEEE Bucharest Power Tech Conference, June 28th - July 2nd, Bucharest, Romania

IEC 61850 Substation to Control Center Communication – Status and Practical Experiences from Projects

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***Abstract*-- Introduced in 2004 edition 1 of standard IEC 61850 defines the communication of intelligent electronic devices within substations. Due its TCP/IP communication platform the standard IEC 61850 is also applicable on wide-area communication technologies. Therefore the standardization working groups focus on new application fields such as substation-to-substation communication and communication from substation to control centers. This paper introduces IEC 61850 substation to control center communication, the current status of standardization and presents experiences gained from practical applications.**

***Index Terms*-- Substation Automation, Engineering, IEC 61850, Proxy, Standardization**

I. Introduction

The international standard IEC 61850 [1] is so far the recent evolutionary step on the way of the development of digital substation automation systems. The history has started in the early 1970s with the first implementations of microprocessor-based tele-control and protection devices. Since then communication between devices got essential in order to realize sophisticated protection, control and automation applications. The communication protocols applied were more or less vendor specific. The interoperable use of devices from different vendors was a challenging task, often solved with additional protocol converters. Today complex applications in distributed configurations are designed with the use of devices of different vendors. Interoperable communication is the main requirement for that approach and IEC 61850 provides the perfect basis.

Edition 1 of IEC 61850 focuses on the interoperable communication within substations. For external communication, so far gateways for protocol conversions are required. Here new approaches like the extension of IEC 61850 for substation-to-substation communication are currently developed [2] in order to provide a seamless communication. The present paper discusses the application of IEC 61850 for substation to control center communication, which is currently investigated by experts from standardization working groups [3].

Basically from new technologies, technical and economic advances over existing solutions are expected. In the context of control center to substation communication this means that solutions based on IEC 61850 offer additional benefits compared to solutions based on the established IEC 60870-5-101 /-104 protocols [4, 5].

For users the economic benefit of a substation in regards to its life cycle is most important. This so-called "total costs of ownership" include costs for engineering, operation, service, modifications, extensions, staff trainings and even for deconstruction. Consequently it is expected, that a new solution based on IEC 61850 can provide contributions for cost saving in nearly each aspect.

For example IEC 61850 offers a standardized data model which spans process to control center level. The data model is described in a uniform and standardized description language – SCL (substation configuration language) [6]. Thus enables the user to exchange and document the application data model in a vendor neutral format. Therefore multiple data entry can be avoided and data quality can be enhanced. As a result the engineering efficiency can be increased significantly by the use of IEC 61850 [7, 8].

In the following section the field of application is introduced. Section III presents the current standardization activities regarding substation-control center communication. Afterwards the current approach including use cases, requirements and concepts is described. The experiences gained from real applications of substation to control center application are presented in section V. Conclusions are summarized in section IV

II. Field of Application

A. Basic Scenario

Information exchange is the fundamental task of substation to control center communication. Figure 1 shows the schema of a power automation system consisting of process, bay, (sub) station and control center level. Information exchange between components and systems is illustrated by connection lines.

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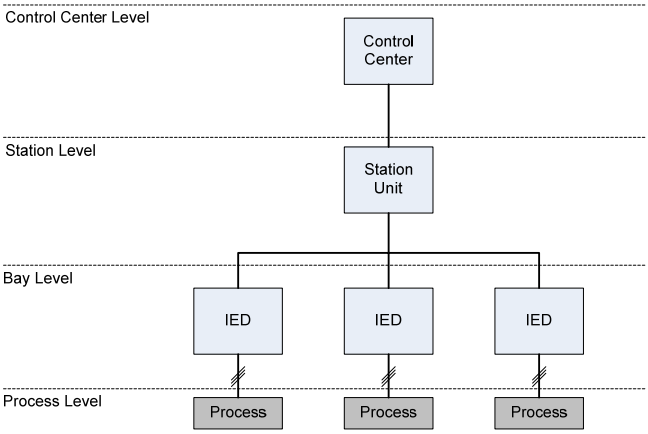

Fig. 1. Schema of power system control and automation systems

Protection, control and supervision of primary equipment systems are the functions that are performed by substation automation systems (SAS) including intelligent electronic devices (IED) and station unit. IED acquire status and measurement information from primary equipment – and in case of control commands or circuit breaker trips – to primary equipment via process interface. Horizontal communication between IED is performed for substation wide functions, e.g. control interlocking. For the purpose of control and supervision, information is exchanged in vertical direction – from IED via station unit to control center, and vice-versa.

B. Communication Standards and Technologies

Table 1 gives an overview of the characteristics of currently used communication technologies in Europe.

TABLE 1
CHARACTERISTICS OF APPLIED COMMUNICATION TECHNOLOGIES (MEDIA: FO – FIBER OPTIC CONNECTION, SYSTEM LEVELS: CONTROL CENTER, STATION, BAY, PROCESS)

Technology	Protocol	Media	System Levels			
			C	S	B	P
Ethernet	IEC 61850	FO, wire		x	x	x
	IEC 60870-5-104	FO, wire	x	x	x	
	Proprietary Protocols	FO, wire	x	x	x	x
Serial Communication	IEC 60870-5-101	FO, wire	x	x	x	
	IEC 60870-5-103	FO, wire		x	x	
	Proprietary Protocols	FO, wire	x	x	x	x
Radio Communication	IEC 61850	Wireless		x	x	
	IEC 60870-5-104	Wireless	x	x	x	
	Proprietary Protocols	Wireless		x	x	

In the course of the historical development of power automation systems a change from the application of serial communication technologies with narrow bandwidths to broadband Ethernet technologies is obvious. In Europe the use of the protocols IEC 60870-5-101 and IEC 60870-5-104 for substation – control center communication is established. Generally the use of proprietary protocols is decreasing due to the users' strong demand for interoperable solutions. The users mainly rely on fiber optic based communication media in substations in order to ensure EMC. The use of wireless communication is quite rare, mainly in the industry domain or in cases of far away situated substations without communication cables.

III. STATUS OF STANDARDIZATION

Currently working group WG 19 of IEC TC 57 discusses the topic substation to control center communication with IEC 61850. The working group focuses on two aspects: "Harmonization of IEC 61970, 61968 and 61850 Models", and "Using IEC 61850 for Substation – Control Center Communication". Whereas the first aspect addresses the harmonization of data models at control center level, the second aspect deals with the use of IEC 61850 for the communication between substations and control centers. A special taskforce has been founded in order to identify technical constraints, to define concepts and to document the findings as technical report IEC 61850-90-2 "Using IEC 61850 for Substation – Control Center Communication".

The contents of the technical report shall include the definition and description of

- Use cases for substation-control center communication
- Communication requirements
- Use of communication services
- Communication architectures
- IEC 61850 modeling
- Use of substation configuration language (SCL)
- Engineering aspects

IV. IEC 61850 BASED SUBSTATION-CONTROL CENTER COMMUNICATION APPROACH

A. Use Cases

The following use cases are typical for substation-control center communication:

- Supervisory control and data acquisition (SCADA)
- Metering
- Time synchronization
- Transmission of disturbance records
- Wide area monitoring
- Power quality monitoring
- Asset supervision
- Parameter and configuration changes
- Engineering

The SCADA use case includes spontaneous and cyclic

transmission of status information or measurements from substation. Also a general interrogation of individual or a group of substations shall be possible. Remote controlling of switchgears from the control center is an essential function.

Metering includes the transmission of integrated totals of measurement values (e.g. energy) from substations.

A time synchronization service is essential to ensure that all substations and IED have a system wide synchronous time. This is the basis for efficient disturbance record analysis and wide area monitoring.

In case of a disturbance event, disturbance records are typically stored in IED or station unit. For disturbance analysis the records are transmitted from substations to the control center [9].

For a wide area monitoring application special measurement values like phasors of voltage and currents are acquired by phasor measurement units (PMU) in substations and transmitted to control centers [10].

Power quality monitoring includes the acquisition of power quality parameters (e.g. harmonics, voltage sags, interruptions, flicker) in individual bays and substations and their transmission to control centers.

In case of asset supervision, distinctive parameters of primary equipment (e.g. circuit breakers, transformers) are acquired by IED. These parameters are transmitted to control centers, where special asset management applications evaluate the asset condition .

Remote parameter and configuration changes from initiated from control center level may include the change of protection settings due to topology changes. Also a remote change of IED from operation to service mode is possible.

The use case engineering incorporates all activities for the design, configuration, documentation, test and commissioning of a substation-control center communication function.

B. Requirements

The functionality of communication to control centers with IEC 61850 poses as well identical requirements to existing IEC 60870-5-101 and IEC 60870-5-104 based solution concepts, but also some special requirements, which are beyond IEC 61850 communication within substations.

Protocol independent requirements are:

- Data concentration
- Common and uniform data designation
- Redundant communication
- Cyber security support

IEC 61850 specific requirements are:

- Standardized description of data model
- Standardized description of communication configuration

In case of wide-area communication networks, which are typically used by transmission and also bigger distribution system operators, often the available bandwidth of the communication link between substation and control center is lower than within substations.

As a result only a subset of the information, that is available in substations, is transmitted to the control center due to reason of information bottlenecks. Therefore it is necessary to concentrate the information before sending to the control center. Further a common and uniform data designation shall be supported, which is independent to the internal designation of the substation. Redundant communication to the control center as well as support of cyber security according IEC 62351 [11] is required.

C. Concept

In order to address the requirements two different configurations can be considered.

1) Configuration with proxy device

Fig. 2 shows a configuration with a proxy device.

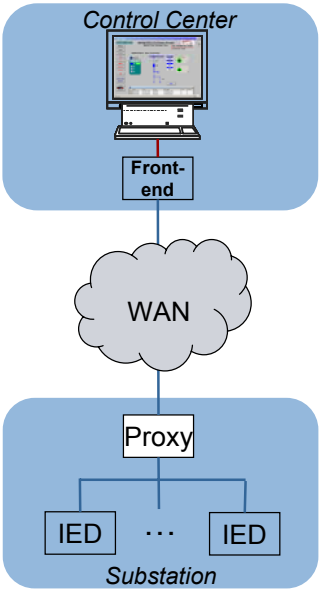

Fig. 2. Configuration with proxy device

The proxy device is a special IED which manages the communication between substation and the communication front-end device of a control center via a wide-area network (WAN). Contrary to gateway devices, which convert different protocols, a proxy device services requests and forwards them on the same protocol.

In the present application the proxy device concentrates the data sent by IED in the substation. Typically only a subset of the data available in IED and exchanged on the station bus is transmitted to the control center. This includes data like switch gear status, essential measurements, alarm and warning indications. Data e.g. for control interlocking (sent by GOOSE service) or protection blocking is only relevant within a substation.

The first IEC 61850 IED available used different data designation profiles. That means that information with identical semantic (eg. trip of overcurrent stage) may have a different data designation:

- Vendor A: *IED1LD1OCPTOC1.Op*
- Vendor B: *IED1PROTPTOC2.Op*

For a system operator it is most important to have a common and uniform data designation profile. A system wide uniform profile eases configuration, testing and service of the communication systems. Therefore the proxy device shall offer a translation function which is able to map different vendor specific designation profiles to a user specific profile.

Furthermore by the use of a proxy device it is possible to decouple the substation network and the WAN logically and physically. In case of huge transmission or distribution system with lots of substations, a direct network connection of the communication front-end device to all IED within substations would result in a high number of TCP/IP connections. This would pose high performance requirements to the communication front-end device. By the use of a proxy device, separate networks can be built. Instead of connections to all IED, the communication front-end device has only one connection to the proxy device per substation. This reduces the number of TCP/IP connections drastically.

Cyber security support is a further function which can be realized by the proxy device. Standard IEC 62351 focuses on methods and concepts for end-to-end security. It addresses the cyber security functions – confidentiality, integrity, availability and non-repudiation. The functions for user authentication and data encryption are implemented in the proxy device. The user can benefit from a secure communication between proxy and communication front-end devices.

2) Configuration without proxy device

In case of a local network offering a high bandwidth and a limited number of substations and IED, a configuration without a proxy device is a reasonable and efficient concept (Fig. 3).

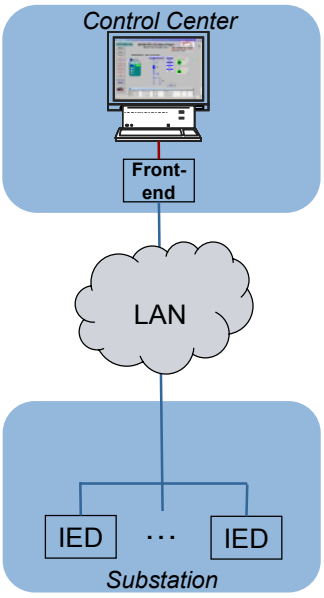

Fig. 3. Configuration without proxy device

Typically this configuration is applicable for industrial power systems or small utilities, where a local area network (LAN) is available. As a consequence expense for a proxy device (hardware, engineering, service, staff trainings) can be saved.

3) Communication redundancy

Depending on availability requirements regarding the substation-control center communication function, a single equipment configuration and a single communication path according Fig. 2 may be sufficient. In order to achieve higher availability levels, configurations which provide redundant equipment and communication path can be used. Fig. 4 shows different redundancy configurations. The availability of configuration A is higher than configuration B due to the use of multiple instances of proxy and communication front-end devices.

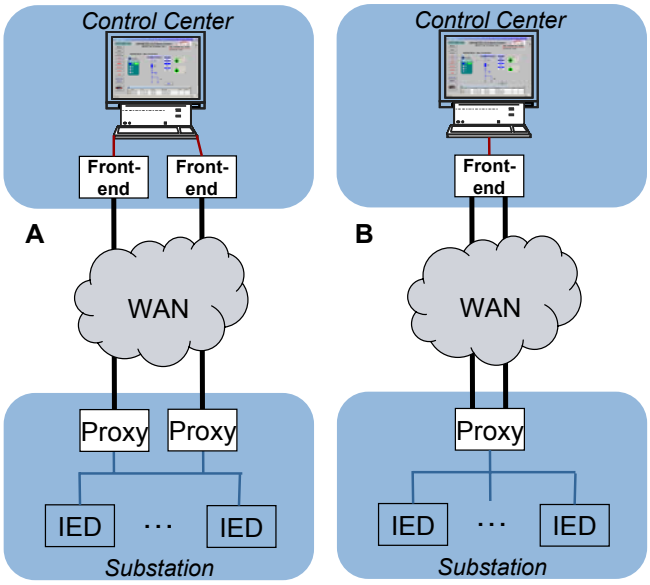

Fig. 4. Redundancy configurations – A: multiple instances of equipment and communication paths, B: single equipment layout and multiple communication paths

4) Engineering

Engineering of the substation-control center communication function can be divided into several activities: design, specification, configuration, parameterization, documentation, test and commissioning.

IEC 61850 introduced SCL as standardized configuration description. Hence the engineering activities use SCL for substation-control center communication.

The configuration of data models and communication parameters of a SAS is described in the system configuration description file (SCD). Consequently data model extensions and additional communication parameters that are necessary for substation-control center communication shall be covered by SCL. In case of a proxy device its data model and communication parameters (e.g. IP addresses, report settings, data sets) shall be described. In case of configurations without proxy device, data sets and report settings of IED that are

dedicated for the transmission to the communication front-end device, are described in SCL as well.

In terms of engineering activities, design includes the design of the communication architecture according functional (e.g. data concentration, number of control centers, control hierarchy concept) and non-functional (e.g. availability, cyber security) requirements. In the following step the specification of the information shall be carried out which shall be transmitted between substation and control center. Configuration as part of the engineering process means creation of the SCL representation of a present substation-control center communication application. Afterwards the equipment like proxy and communication front-end devices is parameterized. Documentation of all these configurations and parameters is essential. The SCL description of the substation-control center communication application provides an ideal basis for an automated end-to-end test.

V. PROJECT EXPERIENCES

Today in several industrial [12] and utility power systems substation to control center communication with IEC 61850 is in operation.

As example the experiences made in an industrial application are presented. The company operates several chemical plants worldwide. Fig. 5 gives an overview of the configuration template which is applied at several plant sites of the company.

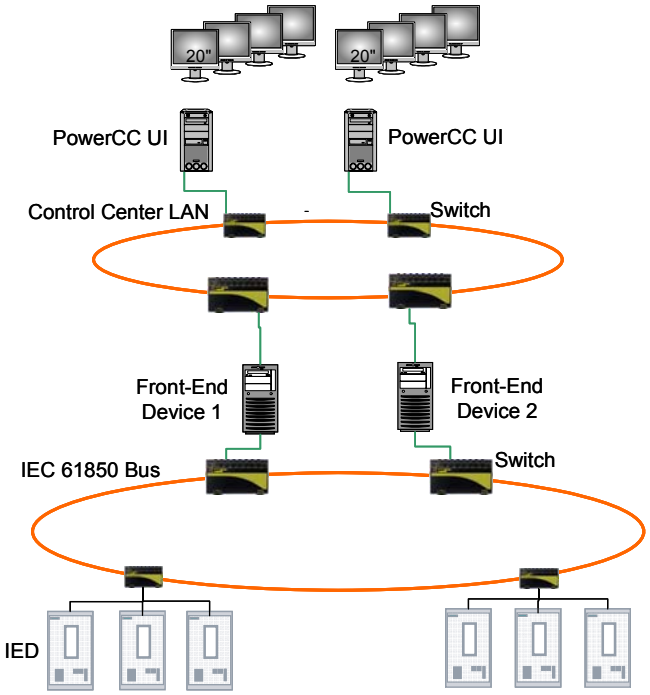

Fig. 5. Configuration of an industrial application

The substations are equipped with local communication networks featuring high bandwidth. Therefore the substation IEDs are connected directly to the control center without the use of a proxy device. For higher availability two communication front-end devices are used.

During engineering significant savings were achieved. By a simple import of the standardized data model description in form of SCL, the control center database was efficiently configured. Efforts for testing were reduced, by using the data model with its uniform data designation from process to control center level. Multiple testing because of gateways was avoided. In conclusion it was practically shown, that the commissioning of substations with IEC 61850 is much more efficient than with other protocols and communication concepts.

VI. CONCLUSION

The use of substation to control center communication with IEC 61850 offers technical and economical benefits for users.

The uniform and seamless system concept, provided by IEC 61850, is an ideal basis for efficiency in engineering, operation and service in substation automation and power system control. Experiences from projects have proven the benefits.

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VIII. BIOGRAPHIES

Heiko Englert (M' 2007) received the Dipl.-Ing. degree and Dr.-Ing. degree in electrical engineering from Saarbrücken University and Darmstadt University of Technology in 1997 and 2002, respectively. After working as research assistant at Institute of Electrical Power System at Darmstadt University of Technology he joined IDS GmbH, Ettlingen, where he was product manager for protection and substations automation systems. Since 2006 he is with Siemens Energy Distribution, Energy Automation as project manager for standardization and regulation management. He is member of IEC TC 57 WG 19 and DKE AK 952.0.1 "Engineering"

Henry Dawidczak, Dipl.Ing-oec., studied in Moscow. He worked in software development for substation automation. He has joined Siemens first in the sales department for SAS in 1991 and since 2001 as a standardization expert for IEC 61850. He is member of IEC TC57 WG10 and WG19, and of the German National Committee (DKE K952). In DKE he is convener of working group DKE AK 952.0.1 "IEC 61850 - Engineering".