

# UTILITIES AND INDUSTRIES OF TODAY: LEADING BY FOLLOWING IEC 61850

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**Abstract – Substations with protection, control and engineering compliant with IEC 61850 have been in operation since November 2004. The benefits gained by the utilities and industries on specification, project execution, operation and maintenance are presented with reference to three projects which have implemented this communication standard.**

**Keywords: communication, substation, automation, protocol, interoperability**

## 1 INTRODUCTION: IEC 61850

In business management, ‘synergy’ means that when one is added to one, the result is more than two. It implies a team can achieve performance higher than that achieved by the same number of individuals working separately. Teamwork exists also in substation automation systems where equipment from different manufacturers functions together. Since protection and control were automated in substations, the co-operation of devices from different manufacturers has been undermined by the large number of communication protocols involved. Being the single communication standard for the world, IEC 61850 upholds the synergy in substation automation systems by permitting interoperability of devices from different manufacturers without the use of protocol converters. It standardises all the anticipated data and communications in substations, including those at the process level, such as current and voltage signals from instrument transformers.

The communication part of a substation automation system contains three fundamental parts [1] namely

- data of the applications
- services for transferring these data
- real communication protocols.

In IEC 61850, these three parts are distinct and standardised separately. The data and the services hardly change in the course of time. For example, an overcurrent protection function always has the trip signal as output data and the transfer of this signal to the circuit breaker must always be fast. In contrast to data and services, the real protocols for implementing this communication can in theory be anything and can change. IEC 61850 standardises the application data, the generic services for transferring the data and specifies the following protocols:

- Manufacturing Message Specification (MMS)
- TCP/IP of the Internet

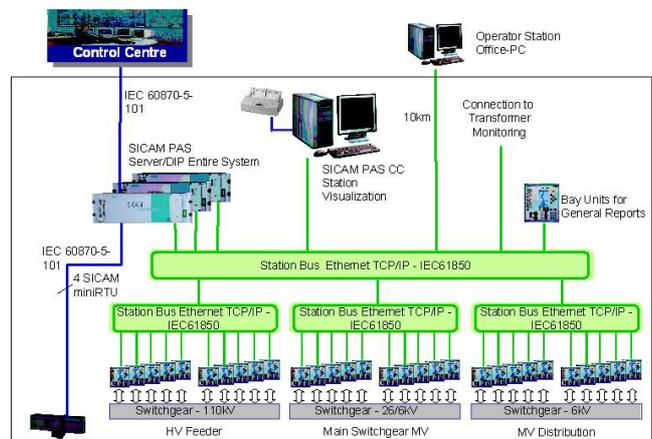
- Ethernet

as the real protocols for substation automation systems. If, owing to advances in communication technology, new protocols are available in the future and can bring benefits to the users, these protocols may replace the presently specified protocols. As a result, the standard keeps pace with technology [2].

## 2 IEC 61850 PROJECTS

Since 2003, the implementation of IEC 61850 has been taking place rapidly for real operations in substations. Orders have been placed by the utilities and industries for installations in a number of countries. Three projects, in which Siemens acts as the lead supplier of the substation automation systems, have been completed or are close to completion. These are the substations Garzweiler, Salzgitter and Winznauschachen.

Wishing to have the flexibility offered by IEC 61850, the German power generating company RWE Power has equipped the Garzweiler substation with equipment compliant with this standard. Three substations of 110kV, 25kV and 6kV respectively supply power to an open cast mine which, from 2005 onwards, will deliver coal to 4 power stations of a total output of 7,5GW. Figure 1 shows the substation automation system. The order was placed in summer 2003 and part of the substation automation system has been in service since April 2005.



**Figure 1:** Substation automation system of the RWE Power Garzweiler substation

The main German engine factory of Volkswagen AG is in Salzgitter, and the car manufacturer has been con-

vinced of the advantages of IEC 61850. In Salzgitter, an intake 110/20kV substation feeds four 20kV distribution substations of the assembly halls and one substation associated with the site-heating facility. For reasons of security of supply, the intake substation comprises three coupled busbars, each fed by an incomer. The intake substation is connected to each distribution substation via a cable covered by differential protection. Figure 2 shows the substation automation system. The order was placed in December 2003 and the substation automation system will be in service in summer 2005.

Intending to gain early experience with IEC 61850, the Swiss distribution network operator AVAG, a company of the Atel Group, requested a 16kV substation be fitted with IEC 61850 automation system. Distance protection would be applied on all of its nine feeders. The switchgear of each feeder would be controlled via a station controller. Figure 3 shows the substation automation system. The order was placed in April 2004 and the substation automation system has been in service since November 2004.

Table 1 summarises the main technical features of the three projects. The benefits due to IEC 61850 are described below with reference to these three projects.

### 3 BENEFITS DUE TO IEC 61850

#### 3.1 Specification

IEC 61850 standardises the name of the data of automation functions. It holds a list of standardised names of all the anticipated functions called logical nodes. The generic services and the real protocols are standardised. A typical specification based on these standardised features would cover the following aspects:

- Network configuration
- Communication stack
- Application functions
- Required services
- Engineering process
- Test

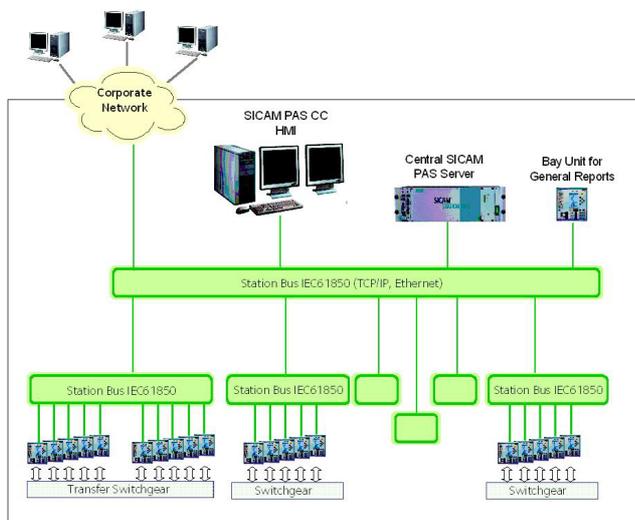


Figure 2: Substation automation system of the Volkswagen Salzgitter substation

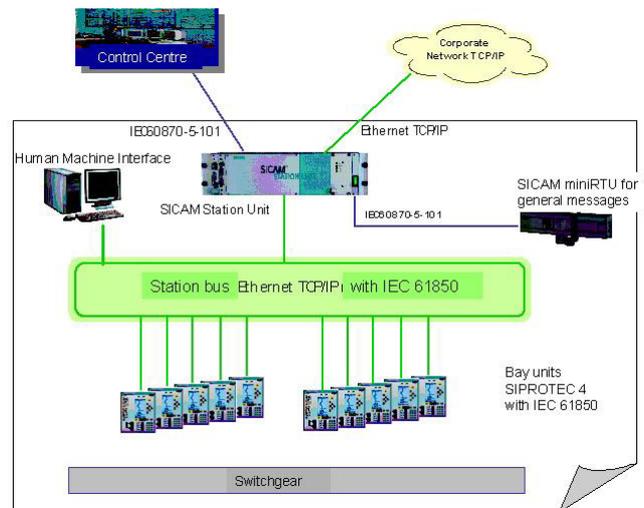


Figure 3: Substation automation system of the Atel Winznaschachen substation

Project	Garzweiler	Salzgitter	Winznaschachen
Voltage (kV)	110, 25, 6	110, 20	16
Number of substations	3	6	1
Number of bays	139	53	9
Number of IEC 61850 devices	134	52	9
Human Machine Interface and station controller	SICAM PAS CC	SICAM PAS CC	SICAM PAS CC
Protocol for remote control/ monitoring	IEC 60870-5-101	-	IEC 60870-5-101

Table 1: Technical information of the Projects Garzweiler, Salzgitter and Winznaschachen.

For example, the communication stack shall contain MMS, TCP/IP and Ethernet. The application functions adhere to standardised logical nodes such as CSWI, XCBR. No ambiguity or misinterpretation would arise between the bidders for the substation automation system and the customers. Although the compliance with IEC 61850 was not requested in all the three projects Garzweiler, Salzgitter and Winznaschachen, the bidders included these IEC standardised features in their offers, and the customers have recognised these as the trend in future specifications.

Substation automation systems compliant with IEC 61850 can be scaled easily. For both the Garzweiler and

Salzgitter projects, the substation lifetime is expected to be 25-30 years, during which expansion of the primary equipment is foreseen. RWE Power and Volkswagen chose IEC 61850 as the standard for the substation because of the scalability of Ethernet. The Ethernet bus can incorporate more nodes easily to deal with the corresponding expansion of the substation automation system and will incur minimum interruption to substation operation.

The communication framework, Ethernet, is highly flexible and gives bidders much freedom in meeting the customers' special requirements. For instance, in Garzweiler, transformers needed to be monitored as well. Because transformer data are standardised in IEC 61850, the lead supplier integrated seamlessly on to the Ethernet station bus a voltage regulator from a tap-changer manufacturer who used IEC 61850 standardised data for transformer monitoring. Nowadays, data networks are also indispensable in substation automation. All the three customers wished to collect all the data in the substation and send them to remote sites or offices. Ethernet allowed the lead supplier to collect the data easily from all the bay devices with the help of the SICAM PAS and send them to remote destinations.

In all three projects, the lead supplier offered a 100Mbit/s optical fibre Ethernet ring with ring redundancy in each substation. When a project involved several substations, the individual rings were tied to a main ring to which the Human Machine Interface (HMI) and other local or remote monitoring and control equipment are connected, as shown in Figures 1 and 2. Should one part of a ring fail, the Ring Management system would re-route the Ethernet telegrams to the healthy part so that the substation automation system would continue to run. This feature met the high security requirements of the three customers.

The standardised protocols MMS, TCP/IP and Ethernet enable the utilities/consultants to adjudicate the bids fairly. It is no longer necessary to compare unlike protocols, for example DNP3.0, Modbus or a proprietary bus, from different manufacturers. Furthermore, not needing to resolve numerous unlike protocols within a substation, the lead supplier focused on optimising the substation automation system and making the overall system cost-effective. Also, the lead supplier could spend valuable time on engineering the interfaces between the IEC 61850 system and external systems such as the IEC 60870-5-101 connection to the control centre, as required in Garzweiler and Winznauschachen.

### 3.2 Design

In the past, utilities, industries and consultants often made the data models in the specification sufficiently general so that a wide variety of manufacturers supporting different protocols could offer their equipment. Now, the standardised data models of IEC 61850 are understood by all the manufacturers and can be shown in the specification. These models can be carried over directly into the design stage, saving time and minimising errors. The lead supplier could start work immedi-

ately after the award of contracts, and there were no long and winding meetings for clarifying the specifications with the customers.

In general, an existing Ethernet structure in a substation can be re-used with little extra design work. However, in the case of the three projects, the customers were experiencing both IEC 61850 and Ethernet on substation level for the first time, and this communication platform was established from new. Nevertheless, from the point of view of the lead supplier, hardware design of the substation automation system was simplified for the following reasons:

- No protocol convertors were required among the devices.
- The Ethernet components used were of industrial grade, readily available and suitable for operation in high-voltage substations. The Ethernet switches needed only minor setting-up on site.
- Fewer components in the substation automation system meant less time spent on co-ordination and fewer review meetings.

The Substation Configuration Description Language of IEC 61850 allows the primary and secondary equipment in the bays to be specified through the System Specification Description file. In most cases, the design staff can establish templates of basic protection and control schemes for typical bays, for example incomer bay, transformer bay. These templates can be modified to suit other similar bays, saving time and reducing errors.

In conventional parallel wiring, each pair of wires carries only one signal and the wires run from one device to another. Preparing the schedules for these multicore cables, the supporting trays, terminal blocks and marshalling boxes is a time-consuming task, let alone the numerous drawings involved. With IEC 61850, the substation data are serial and sent over Ethernet cables. Using this communication medium leads to a significant reduction in the number of multicore cables and the accessories in most substations, and hence a reduction in design efforts. This benefit is more evident at the process level involving primary equipment. In the three projects, although IEC 61850 has been applied at the station and bay levels, the customers have already benefited from the reduction in equipment variety because there is just one type of cable and connectors, which is that for Ethernet, in the whole substation instead of several types of communication cable and accessories.

### 3.3 System Configuration

The Substation Configuration Description Language simplifies the configuration task and is automated via the manufacturer-independent information exchange. There is no need to exchange information on paper. Less time is needed for co-ordination. Because the chance of errors in the information exchange was lower, the lead supplier conducted less rework and retest, and consequently shortened project execution time. The Substation Configuration Description Language underpins the

notion of 'right-first-time'. Working to the common single standard IEC 61850, the staff responsible for configuration did not need to learn or deal with numerous unfamiliar protocols, and they devoted their efforts to making the system up-and-running early. Their experience gained in one project could be quickly applied in another, shortening the execution of projects running in parallel.

Ethernet is so versatile that while being the medium for the transfer of substation automation system data, it is also used for the transfer of configuration data. No specific communication links or specific ports on the devices need to be created for transferring the configuration data.

For the three projects, the substation automation system was set up in the test facilities in Nuremberg, Germany, and tested with full Ethernet cabling. Test personnel did not need to deal with numerous unfamiliar protocols and they could hence focus on fault-finding and fault-rectification. Only the parts with conventional parallel wiring linked to primary equipment were tested on site.

### 3.4 Installation and Commissioning

As Ethernet entails fewer cables and accessories, installation time is reduced. Less cabling means that the chance of connection/termination errors is lower. Together with the absence of protocol convertors, these advantages enabled the lead supplier to meet the short project time stipulated by the three customers, in particular Atel, by reducing installation time and shortening commissioning. Figure 4 shows the commissioning of Winznauschachen substation.



**Figure 4:** Commissioning of Winznauschachen

Over 95% of the local area networks of offices are Ethernet. Standard tools for checking Ethernet systems are readily available and can be applied in substations during commissioning. Such tools were used in the three projects.

Running also on TCP/IP, a portable computer such as a laptop may be moved around in the substation and plugged into any Ethernet switch during commissioning

to display the information about the whole substation. In particular, many tests involve checking the 'cause' at one location and the 'effect' at another location in the substation. Being able to view all the data at a single location helps speed up such tests. In the three projects, this lightened substantially the work of the commissioning staff.

The workplace of technical specialists is often the office, where they are close to their own databases and tools. The specialists could take part in commissioning without leaving the desks and read site data via the corporate network, guiding and offering advice to personnel on several sites anywhere in the world. When the specialists work 'side-by-side' with the site staff in this manner, care should be taken to ensure that the corresponding remote access does not weaken the security of the data network of the customer.

### 3.5 Operation and Maintenance

The customers of all the three projects will see an improvement in the performance of the substation automation system because:

- The data flow experiences no delay otherwise caused by protocol convertors.
- In contrast to polling, Ethernet multicasting allows messages to be sent simultaneously to many receivers and hence faster.
- Bottlenecks, commonly found in other master-slave communication, are not present.
- 100 Mbit/s is the state-of-the-art data rate of Ethernet in substation communication and can barely be achieved by other protocols.

The availability of the substation automation system is expected to be higher because:

- Distributed intelligence is advocated in IEC 61850. Interlocking can be implemented without a central co-ordinating device. Peer-to-peer communication means that a function still runs normally even after one or more devices have failed.
- Ethernet switches entail no collisions and therefore the data throughput is higher.
- Events are reported as soon as they occur, in contrast to master-slave whose polling interval may be so large that the transmission of messages takes longer.

System availability was important to Volkswagen because car engines were manufactured 'just-in-time' and delivered to different production sites. There were practically no warehouses for storing the manufactured units. To meet the reliability requirements in Salzgitter, the lead supplier has supplied the SICAM PAS as the station controller, the station unit of which runs on an embedded operating system, without cooling fan or rotating hard-disk. The lead supplier has further provided the customer with a diagnostic-notebook to enhance operation and maintenance, and the operator can interrogate the data in any device at any Ethernet switch. With the notebook, he can also test the substation automation system and control the switchgear in any bay.

In the Garzweiler and Salzgitter projects, the SICAM PAS CC on the station bus offers a full graphic service platform to the operation personnel on site. All these data can also be accessed by maintenance staff in the offices of Volkswagen via the corporate network, as explained before in the relation to specifications.

The three customers will find maintenance easier because there is less equipment and also because they handle fewer communication protocols. Training effort is reduced because the staff do not deal with a large number of protocols.

#### **4 CONCLUSIONS**

The benefits of the standard IEC 61850 on substation automation have been experienced by utilities and industries with regard to specification, design, configuration, installation, commissioning, operation and maintenance. The communication medium is the fast 100Mbit/s Ethernet and the future-proof standard safeguards the investments of these users. These benefits have been shown in relation to three projects Garzweiler, Salzgitter and Winznauschachen. Other projects are starting and will be reported in forthcoming papers.

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