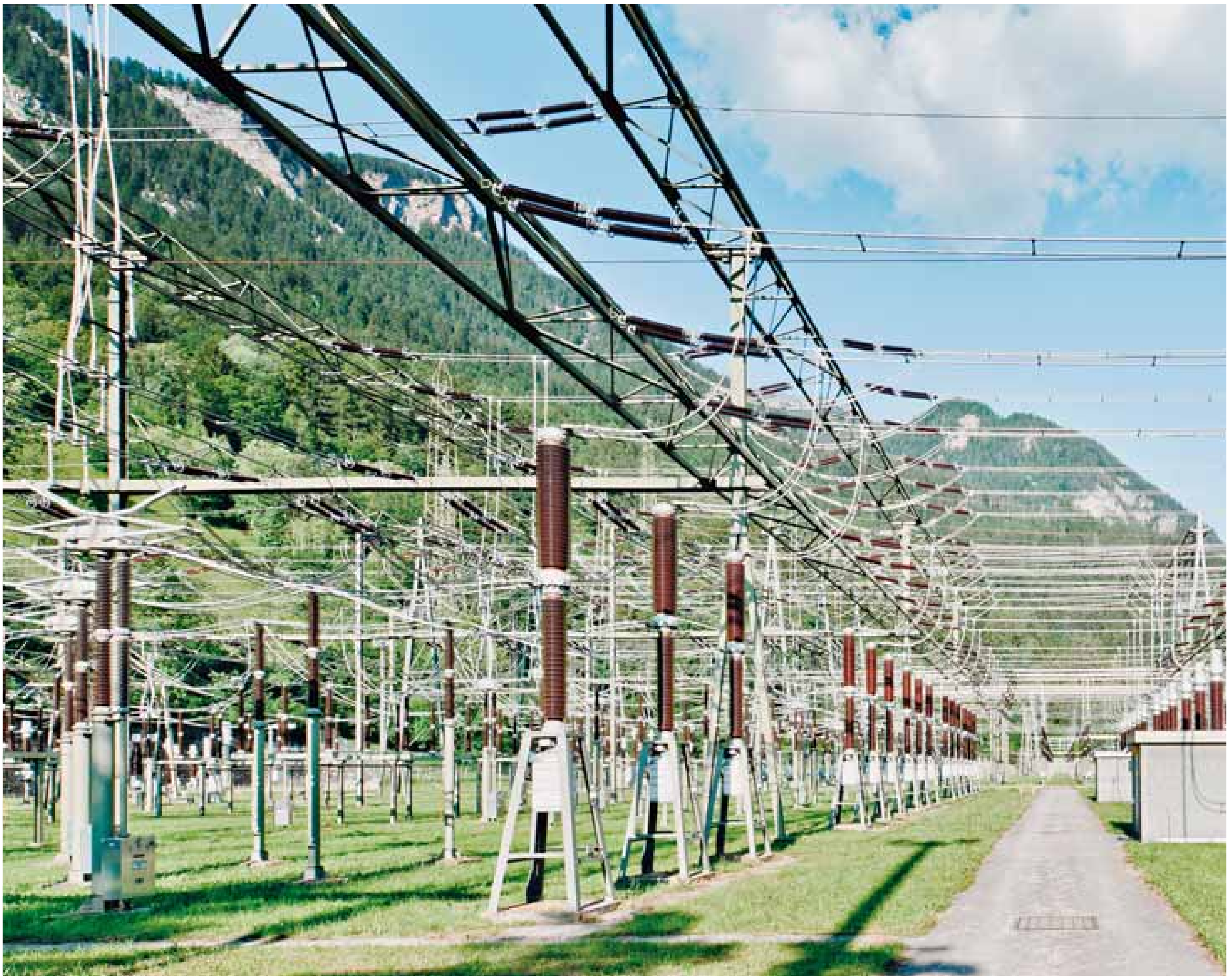


IEC 61850 Edition 2

From substation automation to power utility automation

KLAUS-PETER BRAND, WOLFGANG WIMMER – The final part of IEC 61850 Edition 1 “Communication Networks and Systems in Substation Automation” [1] was published in June 2005. Among the standard’s greatest achievements and benefits are the use of standardized semantics and a formal system description (the latter being the key to efficient engineering of substation automation systems) as well as it being embedded into the broader scope of power-system management. Since its introduction, IEC 61850 has established itself as global standard for substation automation. An example from Switzerland is the system installed in Sils ➔ 1 [2]. This is, however, far from the conclusion of its development. Additional application areas are being considered by IEC. The standard is thus being extended.

The development of the IEC 61850 standard is continuing. This work is primarily aimed at remedying various shortcomings that were identified during the first installations, but it also seeks to enhance its application range – as is reflected in its changed title "Communication Networks and Systems for Power Utilities" [3]. This work is resulting in Edition 2 of the standard, which is being published in 15 parts during 2010.

Expanding into new application areas

IEC 61850 was originally defined exclusively for substation automation systems (including protection applications). It has since been extended to other application areas. These are automation of wind power systems [4], hydro power systems [5], and distributed energy resources such as combined heat and power systems or photovoltaic plants [6]. The fact that the standard is being applied in the domain of distributed energy resources indicates the significance of IEC 61850 for smart grids.

Aspects of the extension of IEC 61850 to these domains include the following:

- The services of IEC 61850 have been proven to fulfill the known requirements of these other domains and may hence be applied without changes. In many cases, only a subset of them is needed.
- The basic substation-automation related data model has to be extended only by additional logical node classes needed for functions from these other domains.
- The communication stack used is very common (especially TCP/IP and Ethernet).

The standard extends beyond the switch yard

There is a significant advantage for utilities if data from substation IEDs can be used directly on higher system levels for control and monitoring purposes, without there being a need for protocol converters or having to handle numerous different protocols. Therefore two working groups of IEC TC57 have looked at the use of IEC 61850 for real-time applications such as line protection and also other applications that involve communication between substations as well as monitoring and control applications involving communication between substations and network control centers. The results will be published as technical reports.

The report that handles communication between substations is published as IEC TR 61850 90 1 [8]. Its results are being integrated into the second edition of the base standard. Besides discussing direct tunneling of Ethernet-level messages on high-bandwidth links, it also looks at the usage of proxy gateways with low-bandwidth links → 2.

The report handling communications between substations and network control centers will be published as IEC TR 61850-90-2 [9] and any resulting add-ons to the base standard will be integrated into an amendment to Edition 2, or at the latest in Edition 3 of the base standard.

Work on a third report handling the automated transformation and mapping between the IEC 61850 data model and the IEC 61970 Common Information Model (CIM, [10]) has just begun.

These extensions do not only concern the application-data model itself, but also the capabilities of the SCL (substation configuration language) to support new data models and enhanced engineering processes.

Remaining challenges from Edition 1

61850-9-2 defines the standardized communication of current and voltage samples across an Ethernet-based serial link. Besides transmitting such analog samples, the link also transmits switch positions, commands and protection trips. According to IEC 61850-8-1, this combination results in a complete process bus between primary and secondary equipment → 3.

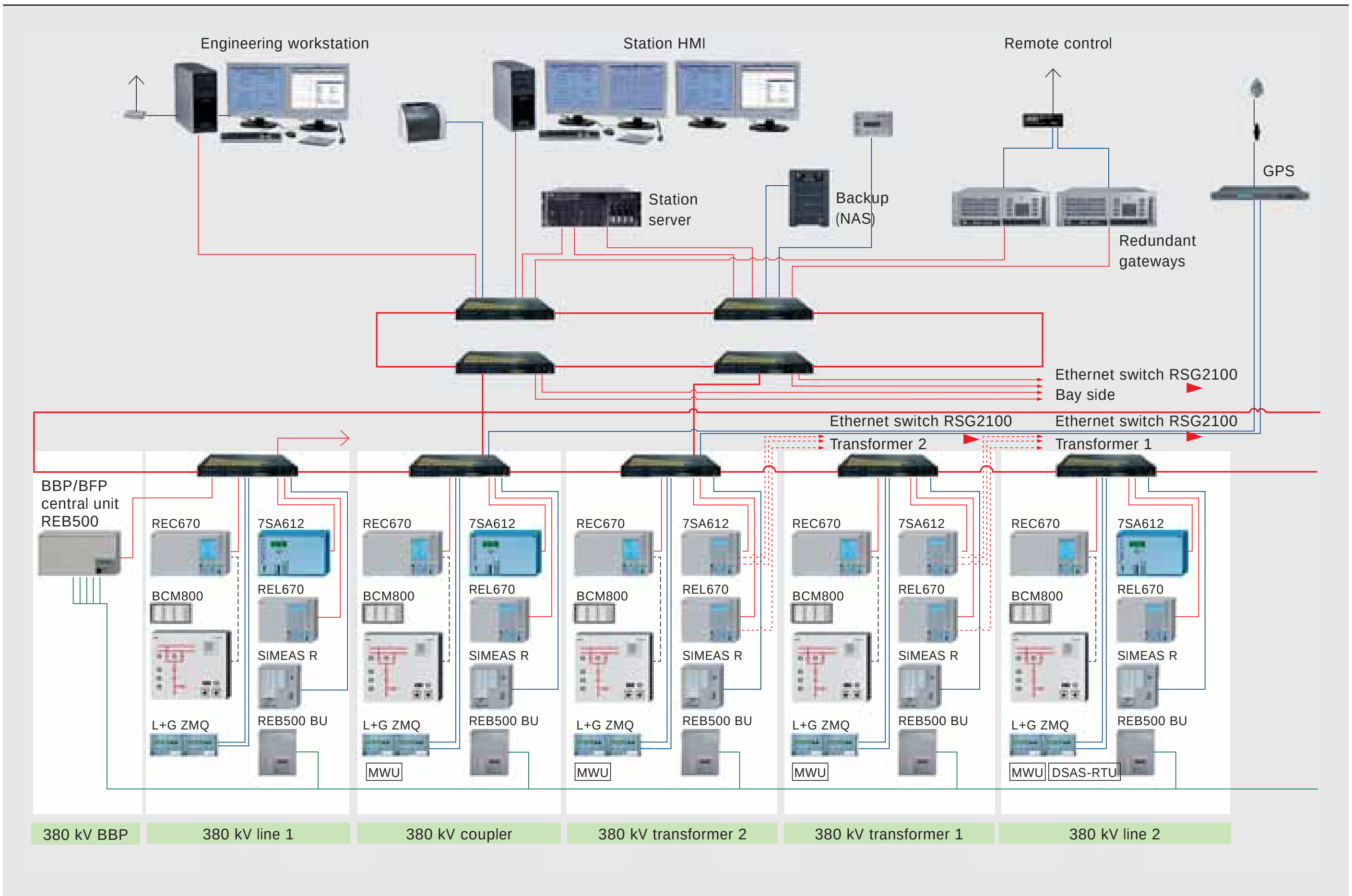
The response time and throughput requirements on this bus are determined mainly by the samples. The advantages of such a process bus are:

- It permits the replacement of many copper cables by a few optical cables (lower cabling costs)
- Optical cables achieve the galvanic decoupling of primary and secondary equipment (makes maintenance and replacement easier).
- The serial interface makes the applications independent of the physical principle of the instrument transformer (electromagnetic, capacitive, optical, others) allowing more flexibility on the primary equipment side.

Edition 1 of the standard did not define a solution for the time synchronization required for the communication of samples at rates in the region of microseconds. Therefore, and to achieve the acceptance of a faster process bus, the user organization, UCA International [11], developed an application recommendation known as IEC 61850-9-2LE (Light Edition). This recommendation is based on the concept of a merging unit (MU) that delivers all current and voltage samples

> IEC 61850 was originally defined exclusively for substation automation systems, but has since been extended to other application areas.

1 IEC 61850 based substation automation system in Sils. This implementation is also discussed on page 38.



from a given bay in a time-synchronized manner. It defines a telegram format containing voltages and currents from the three phases and the zero components. It specifies two sample rates (80 and 256 samples per period) and a time synchronization by a pulse per second (1 pps) with a synchronization accuracy class of T4 (± 4 µs). Meanwhile, a profile of the standard IEEE 1588 [12] is being worked on, which will support high-precision time synchronization across switch-based Ethernet.

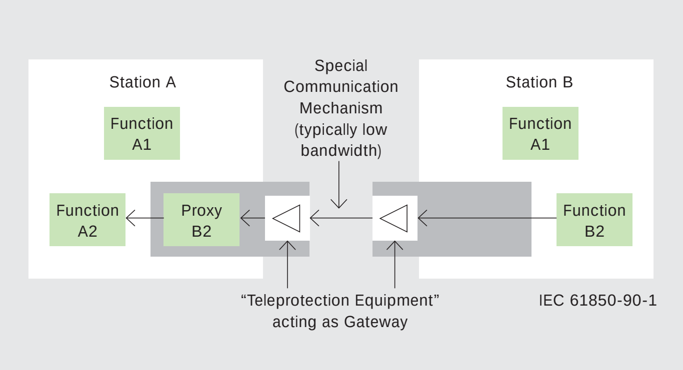
The numerous features and benefits that the process bus offers are considered in a discussion on optimal processes in connection with communication architecture. The interoperable application has been delayed, however, because the dynamic behavior (step and frequency response) of the samples has not been sufficiently defined to guarantee application-level interoperability. The behavior of conventional instrument transformers is defined in the standard IEC 60044 [13] as is the behavior of electronic current and voltage transformers, thus summarizing all NCITs. It is stated, eg, that the electronic current transformer behaves as the conventional current transformer of type TPY for protection. This allows the type testing of the combined set of NCIT and MU. This has been done successfully for ABB's NCIT CP, (combined current and voltage sensors for GIS) which are now ready for use.

Some questions remain unresolved, especially how the signal from a conventional transformer (CIT) is changed due to digitalization in the MU. These questions are addressed by the IEC TC38 (Instrument Transformers) that has started replacing IEC 60444 by new standard IEC 61869 [14] in a step by step manner. It will define in its part 9 the "digital interface" covering the whole issue of MUs. The result will not be available in time to be referenced in Edition 2 of IEC 61850.

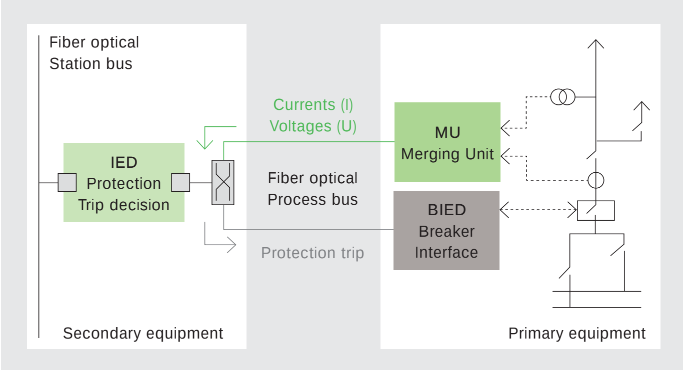
Several manufacturers are already offering MUs as pilot products. However, the electronic interface to a switch (often called a breaker IED or BIED) is rare even as a pilot product. Sometimes "normal" controllers are used in a similar way to BIEDs, eg, by receiving GOOSE (Generic Object Oriented Substation Event) trips from protection devices. This can for ex-

More components will facilitate the adoption of the architecture of the SA system and permit the better physical distribution of the primary equipment, providing the full advantage of the process bus.

2 Communication principles between substations based on IEC 61850



3 Process bus with merging unit (MU), switch interface (BIED) and external Ethernet switch



It is possible to use Edition 2 engineering and SCL descriptions with IEDs still having an Edition 1 data model.

ample be used for the two affected breakers of a 1 ½ breaker switchyard diameter, or for breaker failure protection.

There are also ideas to combine a MU and a BIED into one product. However, this is not a matter for IEC 61850 but for the optimized application of the process bus. The benefits of process bus applications can already be reaped today. More components will facilitate the adoption of the architecture of the SA system and permit the better physical distribution of the primary equipment, providing the full advantage of the process bus.

IEC 61850 Edition 2

Besides the correction of errors and many small details, Edition 2 will contain the add-ons laid out in → 5.

It is planned to publish all parts of Edition 2 with the exception of 7-5xy as an international standard during the course of 2010. The question of when corresponding tools and products will appear on the market depends on the manufacturers and appropriate requirements from customers and is difficult to predict. All error corrections, clarifications and restrictions contained in Edition 2 with respect to Edition 1, however, should already be followed by the next releases of Edition 1 devices. In this context it should also be mentioned that it is possible to use Edition 2 engineering and SCL descriptions with IEDs still having an Edition 1 data model. Edition 2 and all following editions will be backwards compatible to Edition 1 (with the exception of error corrections). A customer or supplier today deciding to apply IEC 61850 Edition 1 will thus benefit from all present advantages and future benefits of this standard. To assure as much compatibility to future editions as possible, it should be verified that the Edition 1 devices used already implement resolutions of all technical problems identified up to Edition 2. This can be done by means of the so called TICS document, which should be available from the manufacturer for each certified IED type.

Beyond Edition 2

IEC standards are being developed in a time-consuming procedure involving commenting and voting by the national committees in several steps and via different drafts as they work towards the final international standard (IS). Therefore, some task forces have already started work on topics for amendments or for a future Edition 3, which will fulfill further user requirements. Some of the topics being considered are:

- Ethernet network architectures within substations including redundancy and Ethernet switch configuration.
- A setup for the supervision and diagnosis of primary equipment, called CMD (condition monitoring and diagnosis).

To provide an overview of the standard's fast-growing data model for both present and future application domains, and to be able to realize extensions more quickly than is possible in the normal standardization process, the introduction of an IEC database for model definitions is under discussion. This would be accessible via Internet. A standardized formal description of the model definitions defined in Edition 2 will help with the rapid integration of new models into the tools.

IEC 61850 and Smart Grids

The discussion around the future of the power grid with more and more decentralized power generation, flexible power buying and high grid reliability often labels this objective as "smart grid". An as-

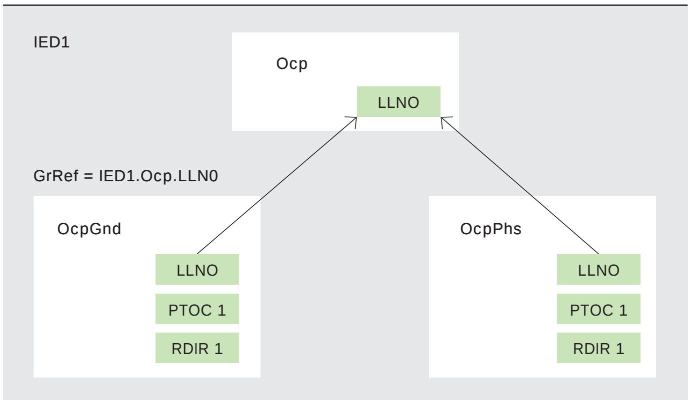
Besides the correction of errors and many small details, Edition 2 of IEC 61850 will contain the following add-ons:

- Clarifications of unclear parts such as:
  - buffered reporting
  - mode switch (test mode)
  - control access hierarchy (local / remote)
- Data model and SCL extensions for communication between substations: discussed above and outlined in ➔ 2
- Support for redundant IED interfaces: discussed in "Seamless redundancy" on pages 57-61 of this *ABB Review* Special Report.
- Data model extensions for new application functions: supervision of non electrical quantities, etc. (These new logical nodes have been mainly introduced by other application domains such as hydro-power plants)
- Statistical evaluations of measurements as contained in the logical nodes MMXU and MMXN: Triggered by power-quality discussions and other application domains such as wind power ➔ 5a.
- Support for tracking and logging of services and service responses: This feature makes service parameters and service handling visible without the use of protocol analyzers by the standard's existing reporting and logging facilities and allows, eg, the logging of negative answers on service requests (negative acknowledgements). This feature is useful both for commissioning and security supervision.
- Management hierarchies of logical devices: Especially complex multifunctional protection IEDs require more functional levels for the management of common parameters. For an example see ➔ 5b: The logical device Ocp controls the mode of the lower level logical devices OpcPhs and OpcGnd by group reference (GrRef) which additionally could be controlled individually.
- New data objects and concepts for testing of function parts in the running system: This feature allows now a standardized application of the test and test-blocked mode which was already introduced in Edition 1 and is now clarified in Edition 2. It supports the handling of test messages in parallel to the real messages.
- SCL extensions to describe new IED properties and better support of engineering processes and retrofit: The data exchange between different projects in a controlled way allows coordinated engineering in parallel running subprojects.
- SCL implementation conformance statement (SICS): stating mandatory and optional features of IED tools and system tools. This feature allows judging the degree of interoperability between different engineering tools, system tools as well as IED tools.
- An informative part 7-5x with examples of modeling important application functions in the system: This part is intended to support common understanding of modeling and to move towards broadly accepted modeling solutions

5a Example for statistical methods (ClcMth) applied on MMXU

MMXU 1	Clc Mth	MMXU 2
TotW Total Active Power	PRES	TotW Total Active Power
TotVAr Total Reactive Power	TRUE_RMS	TotVAr Total Reactive Power
TotVA Total Apparent Power	PEAK_FUNDAMENTAL	TotVA Total Apparent Power
TotPF Average Power Factor	RMS_FUNDAMENTAL	TotPF Average Power Factor
PPV Phase to phase Voltages	MIN	PPV Phase to phase Voltages
V Phase to ground Voltages	MAX	V Phase to ground Voltages
A Phase Currents	AVG	A Phase Currents
....	SDV	....
	PREDICTION	
	RATE	
	......	

5b Management hierarchy for logical devices



sumed prerequisite to the functioning of such a grid is that more information can be made available in a reliable and timely manner to more and more distributed applications and users, permitting control to be optimized. This will assure the grid's stability, make electrical energy available where needed, and permit interactive communication with consumers. This requires the needed data to be made available within a common information network and according to standardized data semantics. This is precisely where IEC 61850 fits in. Therefore IEC 61850 has been taken up alongside IEC 61970 in a smart-grid related report from EPRI [15] and adopted by NIST as a key interest.

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