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IEC 61850 Edition 2 – what does it mean for the end user?

Christoph Brunner	it4power	christoph.brunner@it4power.com
Rodney Hughes	Rodney Hughes Consulting	rgh@rodhughesconsulting.com

1 Abstract

Since it's publication between 2003 and 2005, IEC 61850 has become popular around the world. In the meantime some 4000 substations have been built using IEC 61850 and the concepts are used in domains beyond the substations. IEC 61850 has been identified as one of the key standards for Smart Grids. Over the last years, the standardization bodies have worked on the preparation of Edition 2.

Why a second edition for an apparently successful standard? The Edition 2 fixes the so called TISSUES (technical issues) by adding clarification and solving inconsistencies. As such it is important for product developers, but is it of any interest for the end user?

The answer to this is a clear yes. First of all, the second edition of the standard improves the interoperability between the products. But it is more than that. The second edition adds as well many new features that address requirements of the user that has to build a system based on IEC 61850.

The paper presents the Edition 2 of IEC 61850 from the user perspective. New functionalities like the extension of the scope beyond the substation including as one example protection communication between substations will be discussed. Another important topic is the enhancements of the specifications for testing support. Once integrated into products, this will provide significant benefits for both the testing during the commissioning of the substation as well as for routine testing. The extension of the engineering support through the substation configuration language to allow the exchange of configuration information across projects will facilitate larger projects and a system wide application of the standard. Finally clarifications in the specification of the requirements on the engineering tools will improve the tool interoperability and lead to tools that integrate the IEC 61850 concepts in the design philosophy.

The paper addresses as well the important aspect of backwards compatibility of Edition 2 towards Edition 1. It is an important requirement, that future new devices can coexist in a substation with Edition 1 devices as well as it is important that the engineering files based on IEC 61850 substation configuration language can be reused.

2 Improving interoperability

Naturally the Standard itself has been developed to establish the required engineering process and the vast range of required functional definitions and elements for devices to be interoperable. We have already learnt that interoperability is not a "blind plug and play" just because the device conforms to the Standard. The Standard establishes a capability for interoperability which requires the users to first consider and specify what is needed for the implementation they wish to create – an IED which does not have the required functionality you specifically need will never be interoperable with the system but that is the fault of the user, not the Standard or IED being immature.

Edition 1 of the IEC 61850 Standard was developed between 1995 and 2005. It consists of 14 individual parts and more than 2000 pages. It is obvious that a specification of that size could not be perfect from the very beginning. It was only with the first implementations that it was realized that some of the specifications were ambiguous and could be interpreted differently by different IED development engineers or Systems Integrators. In some cases, the different parts of the standard within themselves were inconsistent.

As a consequence, a process was required that allowed an efficient way to find solutions for these gaps in the specifications that where supported by the standardization bodies and that would end up later in the revision of the standard. Therefore, in cooperation between the standardization working group and the UCA international users group, what was called the "TISSUE" (**T**echnical **Issue**) process has been created. The process is supported by a web site, where the TISSUES are reported by the users and where solutions proposed by the editors of the standard are published.

These TISSUEs provided one first major input for the Edition 2 of the standard. In addition, with the increasing desire of using IEC 61850 concepts as well in other domains than the originally limited scope of the substation automation, new requirements for the basic modeling concepts were created.

While many of the TISSUES are of interest for the development teams of the device vendors, and improve the communication interoperability, there are other TISSUES related to the modeling. Also, with Edition 2 it is planned to issue a technical report describing how to model applications using the logical nodes as building blocks. As an overall result, it can be expected that the models in the different devices will be improved. This will make it easier for the user to build a system with devices from different manufacturers.

IEC 61850 engineering tools based on Edition 1 sometimes lack some of the functionality or sometimes they have overlapping functionality which makes the engineering process more complicated. Edition 2 adds clarifications to the engineering process and defines the responsibilities and tasks of IED tools versus system tools. Conformance statements for the various engineering tools have been added to the standard. This will allow doing conformance testing of the tools in the future.

Clarification has been added to the part 6 concerning the different file types in particular the IED capability description. The ICD file shall represent a template for an implementable IED type. With regard to a multifunctional IED platform, that means, that there may exist several different ICD files, each of them representing an implementable subset of all the functionalities supported by the platform. This is illustrated in Figure 1~~Figure 1~~.

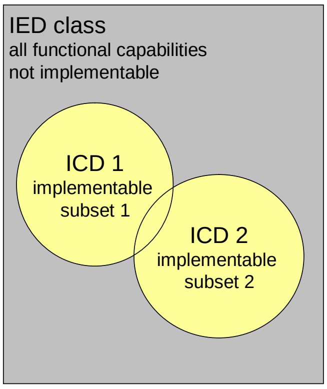

Figure 1 – ICD files describing implementable IED types of a general IED class

Further, a new file type has been introduced to differentiate between an IED type (the ICD file) that can be instantiated to build a system and a file already representing an instance of an IED. For that, a new file type IID (instantiated IED description) has been introduced.

With Edition 2 implemented in the Engineering tools, the design process will benefit making the system integration more efficient.

Another new SCL variant with the file type SED (system exchange description) shall be used to exchange information between different engineering projects. This may be required to exchange engineering information between two substations if these two substations are exchanging information e.g. for protection schemes using IEC 61850 native messages. It will as well support the possibility to split a larger project into two individual projects (e.g. per voltage level) and exchange engineering information between them.

3 Documenting configuration information

One of the benefits of IEC 61850 is the online verification of configuration information. Based on the self-descriptive services, an IEC 61850 client can retrieve the complete model including all configuration information from a device. This can be used to create an application that verifies the actual configuration of the devices against the configuration file. However, in Edition 1, the online configuration information available is basically limited to the model as such including the communication configuration with control blocks and datasets and to configuration parameters as well as settings. Signal flows between functional elements implemented in logical nodes could not be retrieved from the device; they were only available in the configuration file.

Edition 2 adds the possibility to provide information about input references. An example is shown in Figure 2~~Figure 2~~. In that example, the trip signal from the protection function in IED1 is used to initiate the breaker failure function in IED2. That trip signal is transmitted within a GOOSE message to which IED2 subscribes. A data object **InRef** in the logical node RBRF of IED2 points to the source signal.

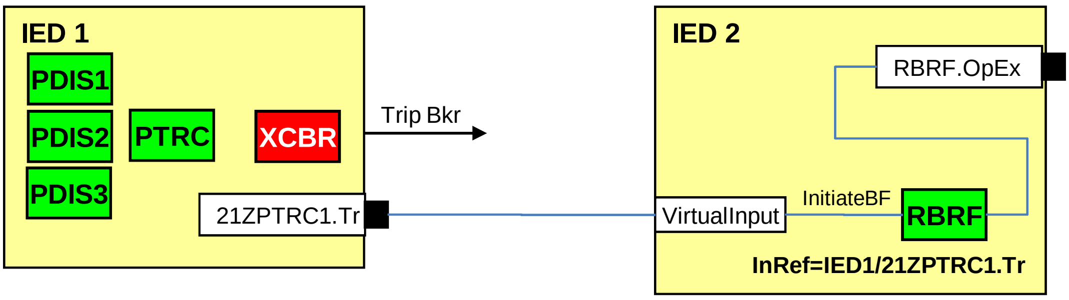

Figure 2 – Signal flow between IEDs

The data object **InRef** can be instantiated as many times as needed in each logical node. It has to be noted, that for a signal referred to with **InRef**, there is no semantic interpretation behind concerning the use of that signal. In our example, the usage is to initiate the breaker failure function, but this is a local issue and cannot be documented. However, for the special case of dynamic blocking, another data object **BlkRef** is defined. This data object points to a source signal that is used as a dynamic blocking signal.

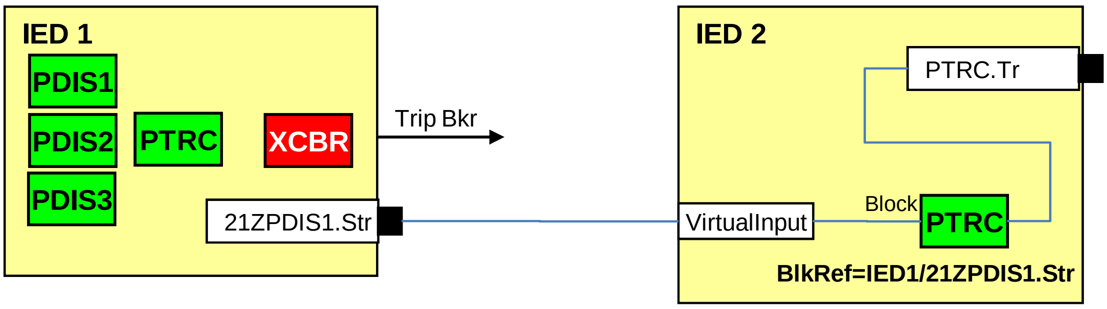

Figure 3 – Reference to dynamic blocking signal

Figure 3~~Figure 3~~ provides the example of reverse blocking. If IED1 detects the fault, the trip of IED2 will be blocked. For that purpose, the start condition of any protection function in IED1 is sent as a blocking signal to IED2. Like the data object **InRef**, the data object **BlkRef** can be instantiated multiple times.

Besides the reference to the source data, the data objects **InRef** and **BlkRef** have as well a reference to the control block that describes the communication service used to transmit the information. In the example above assuming GOOSE messaging, the reference would point to the related GOOSE control block in IED1.

4 Testing support

IEC 61850 Edition 1 already had many different features that could be used for testing. These features included:

1. The possibility to put a function or a functional element in test mode. IEC 61850 provides the possibility to put logical nodes or logical devices in a test mode.
2. The possibility to characterize a GOOSE message as a message being sent for test purpose.
3. The possibility to characterize a service of the control model as being sent for test purpose.
4. The possibility to flag any value sent from a server in the quality as a value for test purpose.

However, Edition 1 was not very specific on how to use these features. As a consequence, they were not supported by the vendors since interoperability could not be guaranteed. This has been improved with Edition 2. Besides more detailed specifications on how to use the existing features, additional features have been added.

4.1 Test mode of a function

A logical node or a logical device can be put in test mode using the data object **Mod** of the LN or of LLN0. The behavior is explained in Figure 4~~Figure 4~~ and Figure 5~~Figure 5~~. A command to operate can be either initiated by a control operation or by a GOOSE message that is interpreted by the subscriber as a command. If the command is initiated with the test flag set to FALSE, it will only be executed if the function (LN or logical device) is "ON". If the device is set to test more, it will not execute the command (Figure 4~~Figure 4~~).

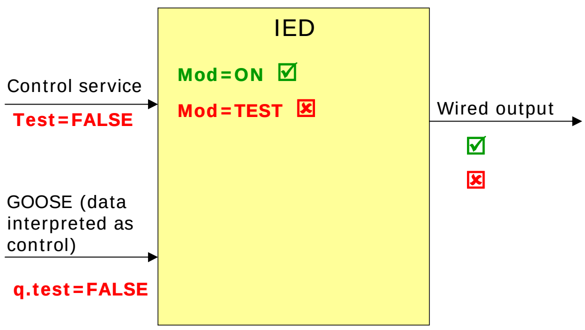

Figure 4 – Command with Test=FALSE

If the command is initiated with the test flag set to TRUE, it will not be executed, if the function is "ON". If the function is "TEST", the command will be executed and a wired output (e.g. a trip signal to a breaker) will be generated. If the function is set to "TEST-BLOCKED", the command will be processed; all the reactions (e.g. sending a command confirmation) will be produced, but no wired output to the process will be activated (Figure 5~~Figure 5~~). The mode "TEST-BLOCKED" is particularly useful while performing tests with a device connected to the process.

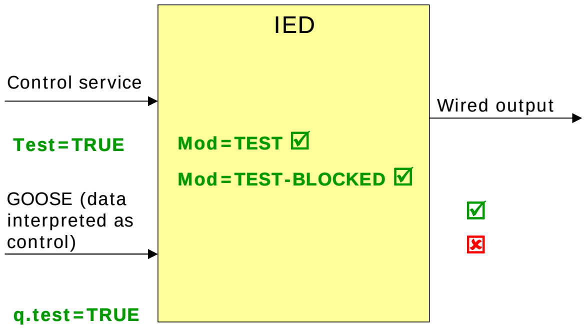

Figure 5 – Command with Test=TRUE

4.2 Simulation of messages

Another feature that has been added to Edition 2 is the possibility, to subscribe to GOOSE messages or sampled value messages from simulation or test equipment. The approach is explained in Figure 6~~Figure 6~~. GOOSE or sampled value messages have a flag indicating if the message is the original message or if it is a message produced by a simulation. On the other side, the IED has in the logical node LPHD (the logical node for the physical device or IED) a data object defining, if the IED shall receive the original GOOSE or sampled value messages or simulated ones. If the data object **Sim** is set to TRUE, the IED will receive for all GOOSE messages it is subscribing the ones with the simulation flag set to TRUE. If for a specific GOOSE message no simulated message exists, it will continue to receive the original message. That feature can only be activated for the whole IED, since the IED shall receive either the simulated message or the original message. Receiving both messages at the same time would create a different load situation and therefore create wrong test results.

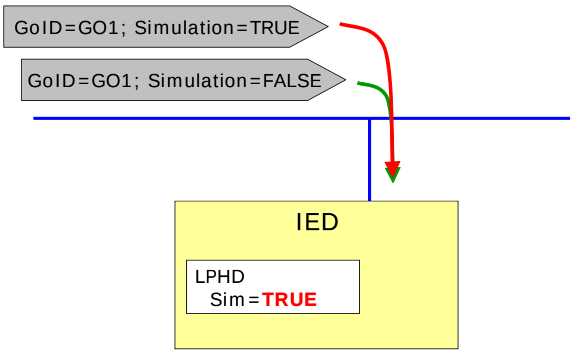

Figure 6 – Simulation of a GOOSE message

4.3 Mirroring control information

A third feature that has been added is the mirroring of control information. This supports the possibility, to test and measure the performance of a control operation while the device is connected to the system.

A control command is applied to a controllable data object. As soon as a command has been received, the device shall activate the data attribute **opRcvd**. The device shall then process the command. If the command is accepted, the data attribute **opOk** shall be activated with the same timing (e.g. pulse length) of the wired output. The data attribute **tOpOk** shall be the time stamp of the wired output and **opOk**.

These data attributes are produced independently if the wired output is produced or not – the wired output shall not be produced if the function is in mode TEST-BLOCKED. They allow therefore an evaluation of the function including the performance without producing an output.

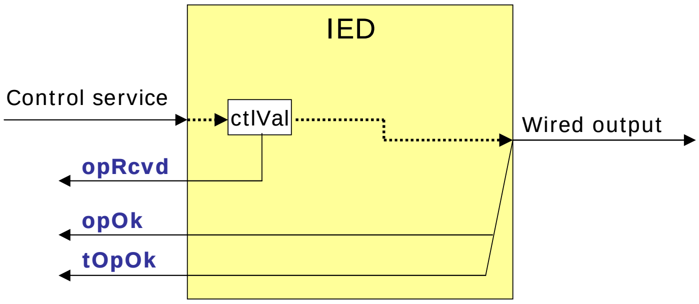

Figure 7 – Mirroring of control information

4.4 Isolating and testing a device in the system

Combining the mechanisms described in the previous sections, it is possible to test a device that is connected to the system. We will explain that with a short example shown in Figure 8~~Figure 8~~.

Let's assume we want to test the performance of a main 1 protection that receives sampled values from a merging unit and trips the breaker through a breaker IED over a process bus. In the LN LPHD of the main 1 protection relay, the data object **Sim** shall be set to TRUE, the logical device for the protection function shall be set to the mode "TEST" and the logical node XCBR as interface to the circuit breaker shall be set to the mode "TEST-BLOCKED". A test device shall send sampled values with the same identification as the ones normally received by the protection relay but with the Simulation flag set to TRUE.

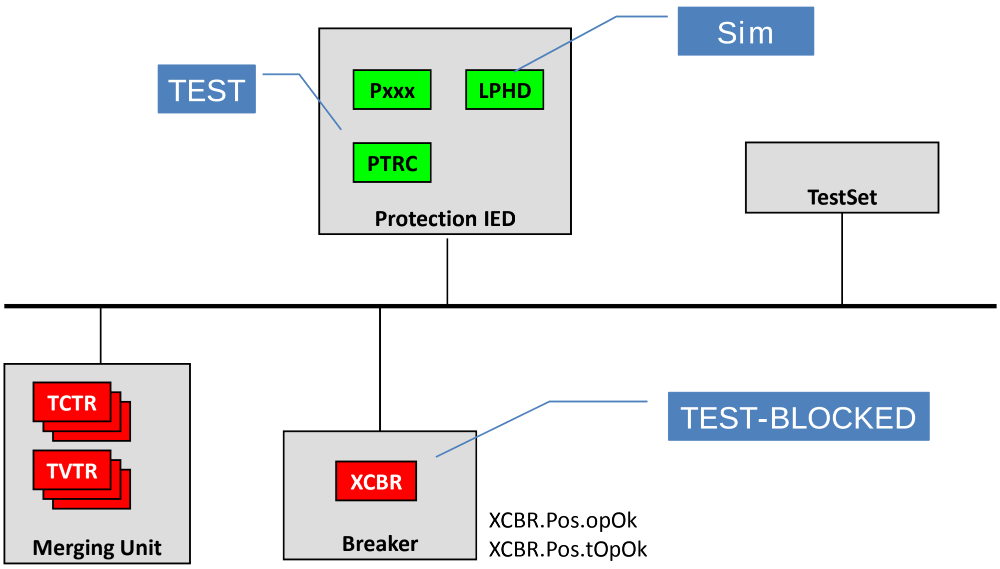

Figure 8 – Testing Example

The protection device will now receive the sampled values from the test device and will initiate a trip. The trip is sent as a GOOSE message with the quality flag of the trip signal set to "test" (PTRC.Tr.q.test=TRUE). The XCBR will receive and process that trip; however no output will be generated since the LN is in mode TEST-BLOCKED. The output can be verified through the data attribute **XCBR.Pos.opOk** and the timing can be measured through the data attribute **XCBR.Pos.tOpOk**.

4.5 Advanced simulation possibilities

Finally, enhanced simulation possibilities that can be used for functional testing have been added. The concept is explained in Figure 9Figure 9. As described earlier, with Edition 2, the possibility do describe references to inputs of a logical node has been added. This is done through multiple instances of data objects **InRef** of the CDC ORG. That data object has two data attributes providing object references: one as a reference to the object normally used as input; the other one as a reference to a data object used for testing. By activating the data attribute **tstEna**, the function realized in the LN shall use the data object referred to by the test reference as input instead of the data object used for normal operation.

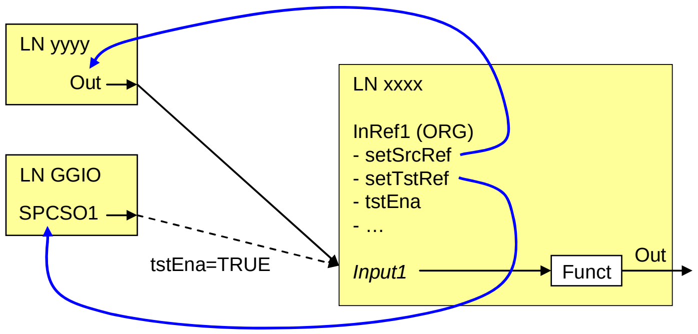

Figure 9 – Simulated inputs

With that feature, it is as an example possible to test a logic function like a interlocking function. Instead of taking the real position indications of the different switches as inputs, the logical node (in that case CILO), can be set to use inputs from e.g. a logical node GGIO. A test application can now easily modify the different data objects of the LN GGIO to simulate the test patterns that shall be verified. That logical node can be external (the data objects being received through GOOSE messages) or it can be implemented in the IED itself for testing support.

Note that while that method allows a detailed functional testing with individually simulated inputs, it may not necessarily be used for performance testing. Since individual inputs are switched, that may change the situation concerning the GOOSE messages to be subscribed in order to receive the new inputs and therefore, the dynamic behavior may be changed.

5 New functionality

5.1 Modelling extensions

New models have been added to IEC 61850 Edition 2 that will support the use of IEC 61850 in further devices. As one example, power quality meters may now support IEC 61850. In IEC 61850-7-4, new logical nodes for power quality measurement have been added and some of the existing measurement logical nodes have been extended. Examples of the new logical nodes are:

5. QFVR for frequency variation
6. QITR for current transient
7. QIUB for current unbalance variation

As an example, meters may now also model statistical evaluated information using IEC 61850. New basic concepts have been introduced to model different statistical evaluations, e.g. to determine an average value of a measurement evaluated during a certain duration. There is significant flexibility provided to configure the evaluation duration as a fixed period or a sliding window. Using the log function, it is possible to create a history of the statistic values.

Also, since Edition 2 it will be possible to do communication between substations – e.g. for distance protection schemes or line differential protection – with IEC 61850. The Edition 2 incorporated the additional definitions made in the technical report IEC 61850-90-1. From a communication viewpoint, two approaches are supported for the communication between substations. In the first approach using regular teleprotection channels, a teleprotection communication device is converting GOOSE messages with binary information from the local IEC 61850 communication to the teleprotection signaling. This is called the gateway approach and is shown in Figure 10Figure 10.

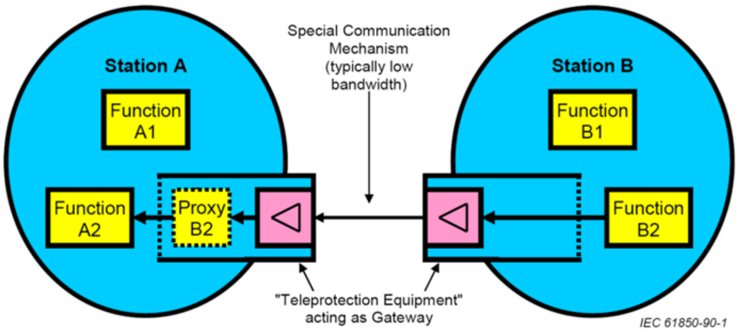

Figure 10 – Gateway approach

The second approach assumes communication channels between the substations with higher bandwidth that can tunnel a GOOSE message to the other substation. This is shown in Figure 11Figure 11. It has to be noted that for the gateway approach, the teleprotection equipment is creating a "Proxy" model for the source data. For the tunneling approach, the source data is directly "visible" as part of the GOOSE message.

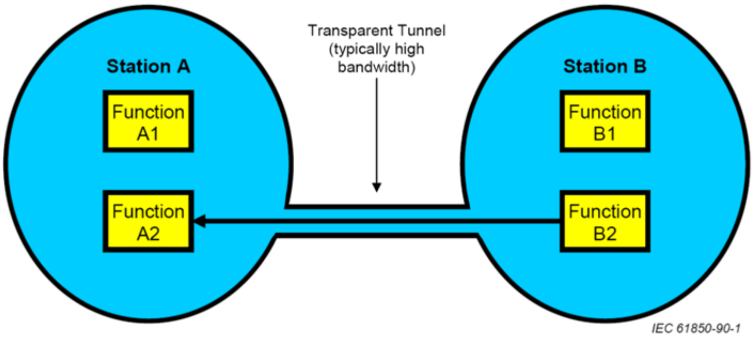

Figure 11 – Tunneling approach for communication between substations

The model for a distance protection function is shown in Figure 12Figure 12. The PSCH logical node is modeling the protection scheme implementation while the LN IPTC describes the behavior of the teleprotection equipment and communication channels.

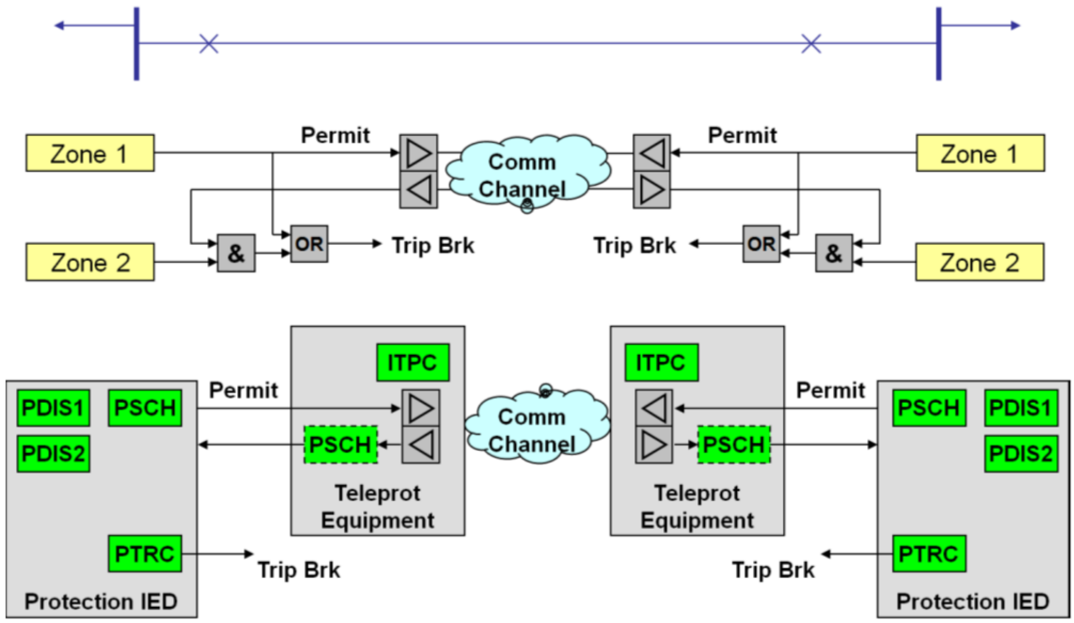

Figure 12 – Distance scheme implemented in gateway approach

Using tunneling approach, the teleprotection equipment with its logical nodes would simply go away.

5.2 Communication – Redundancy

The Edition 1 of IEC 61850 did not specify any specific solutions to implement redundancy. Nevertheless, already in Edition 1 it is possible to implement a redundancy of the communication network like a ring network. This is outside the scope of IEC 61850. The system integrator can decide to build a ring network using switches that support a certain ring protocol like e.g. rapid spanning tree protocol. This will not affect the behavior of the communication interface of the IEDs. Also, already with Edition 1 it was possible to build redundancy by duplicating functionality. A main 1 and main 2 protections is such an approach.

With Edition 2, additional requirements for redundancy have been solved. This included the case, where an IED shall have two connections to the network. The main reason here is, to avoid that the connection to an IED is lost, if the IED is connected through only one interface to one switch and that switch fails.

To solve these requirements, IEC 61850-8-1 and -9-2, Edition 2 introduce the option to include on of the following redundancy protocols:

- parallel redundancy protocol (PRP)
- high availability seamless redundancy (HSR)

Both protocols are defined in IEC 62439-3.

6 Compatibility issues

When preparing a second Edition of a standard, the immediate question to answer to an end user is, what this means for the equipment he bought that supports the Edition 1. And the question from vendors is, what it means concerning the investment made in product development.

From the beginning of the work on Edition 2, backwards compatibility was a major concern. As a supporting element, the standard already had built in the concept of name spaces supporting different versions. As such, one of the basic requirements, the possibility to identify a version that is supported by a particular device, was fulfilled.

As a minimum requirement for backwards compatibility stands the need to be able to use IEC 61850 Edition 1 devices as server in a mixed environment with both Edition 1 and Edition 2 devices. This is essential to allow a future extension of an existing substation without the need to upgrade the already installed devices and therefore to perform a full test of the system again. Also, it shall be possible to reuse existing SCL files.

There are different levels of backwards compatibility that need to be discussed individually:

- compatibility of the communication
- compatibility of the application models
- compatibility of the tools

6.1 Compatibility of the communication

The changes that have been made to the communication services were limited to resolving some ambiguous specifications mainly in the context of buffered reporting. These are based on TISSUE resolutions and they were already required to be implemented for Edition 1 devices in order to achieve interoperability. So no major problems are expected in that area.

6.2 Compatibility of the application models

In that area, some clarifications on existing objects have been required. They could be solved either in a way it was backwards compatible or the object as it was defined in Edition 1 could not be used as such anyway. Besides that, most of the changes were related to extensions and new functionality. When a device shall support that new functionality, it needs of course support as well Edition 2. While such a device may coexist with Edition 1 devices, it may however require that a client that uses that new functionality, needs to be upgrade to Edition 2.

6.3 Compatibility of the tools

This is the most challenging area. It is obvious, that in an engineering environment, there may always be a mix of tools supporting different Editions. Not only shall it be possible that a tool designed for Edition 2 can import or export SCL files to other tools that support only Edition 1. It may as well be required that a vendor tool at the same time needs to be able to support its new Edition 2 devices as well as the old Edition 1 devices a customer may have.

Mechanisms supporting these requirements have been built into the new version of the Substation Configuration Language.

7 Increasing Human Interoperability with IEC 61850 Systems

In Edition 2 we see the inclusion of specific elements designed to support human interaction with the system during maintenance and operation procedures – “Human Interoperability” – such as the test capabilities outlined in Section 4 above.

With the new capabilities provided in Edition 2 comes the possibility for new innovative solutions to solve the famous question:

“How does an operator isolate a GOOSE?”

Conventional wire based secondary systems incorporate numerous switches, push buttons, isolating links, test points and indicators as typically shown in Figure 13~~Figure 13~~ for technicians and operators to use when operating, testing or maintaining the system.

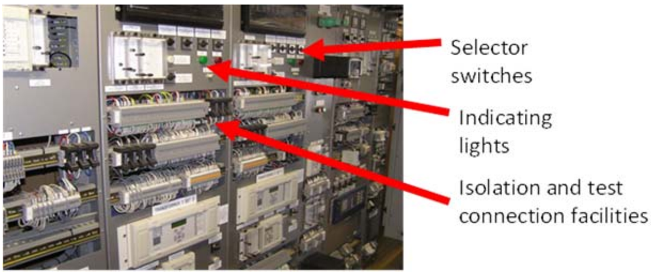

Figure 13 - Operator facilities in wire based systems

Fundamental to every substation is the process of interrupting a signal to make the automation system, individual IEDs and individual function of an IED safe for testing, or replacement.

Facilities must be provided for operators and technicians which:

- Are familiar in every substation (not confuse operators)
- Are safe to use (for personnel and substation operation)
- Maintain cyber security
- Assist and automate maintenance procedures
- Itself be easy to maintain & replace

It is not safe or feasible to simply disconnect the LAN cable.

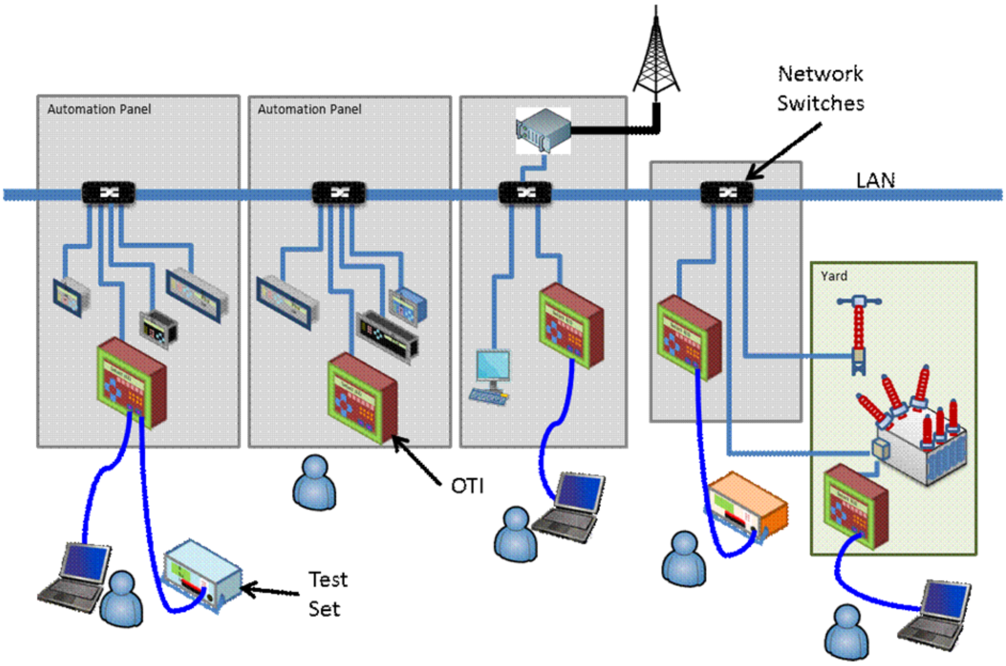

Figure 14 - Operator & Test Interface Application

The asset owner and system maintainer therefore needs an Operator and Test Interface (OTI) which permits humans to interact with the virtual systems to undertake a variety of tasks in the substation quickly, efficiently and safely:

- Control the system: e.g. Setting Group selection, Function enable/disable, Switch on/off ...
- Isolate devices and functions
- Test functions, devices and systems
- Replace devices
- Install new devices

The OTI is a patented application based on the same reliable hardware and software platforms as the automation IEDs they control and can be mounted as part of the fixed installation at the required control location as shown in Figure 13Figure 13.

The patented OTI therefore satisfies the “Human Interoperability” requirements of

- Front access
- No special equipment requirement
- Clear individual labeling
- Single function control
- Ease of control
- Independent of choice of IED suppliers
- Independent of the system integrator
- Standardized procedural sequences
- Not dependent on number of buttons/indicators on different IEDs
- Direct function status indication
- Controls directly related to specific panel
- Can be used with conventional controls

8 Conclusion

IEC 61850 Edition 2 is an improved and enhanced specification, not a complete version replacement, which eliminates many inconsistencies of Edition 1 and therefore is of major importance for inclusion in current product development. Edition 2 also introduces many new features that are of significant interest for the end user in the following three main areas: Improving interoperability and the design process – improving the testing possibilities – providing the possibility to extend the areas where 61850 is applied. And still – IEC 61850 Edition 2 is backwards compatible to the maximum extent.

For the user therefore, IEC 61850 Edition 2 brings the confidence in the experiences and solutions that have been implemented using the first Edition and enhances the capabilities in the true spirit of continued technical innovation.

References

1. CIGRE Australia SEAPAC 2011, Paper 37, “ Experiences of IEC 61850 Engineering – Designing good systems the right way.”, R Hughes & C. Brunner, March 2011
2. CIGRE Australia SEAPAC 2011, Paper 39, “Experiences of IEC 61850 Engineering – Designing good systems the right way”, R Hughes & C. Brunner, March 2011

Biography

Christoph Brunner

Christoph Brunner has graduated as electrical engineer at the Swiss Federal Institute of Technology in 1983. He is Utility Industry professional with over 25 years of industry experience with both knowledge across several areas within the Utility Industry and of technologies from the Automation Industry. He is president of it4power in Switzerland, a consulting company to the power industry. He has worked as a project manager at ABB Switzerland Ltd in the business area Power Technology Products in Zurich / Switzerland where he was responsible for the process close communication architecture of the substation automation system. He is convenor of the working group (WG) 10 of the IEC TC57 and member of WG 17, 18 and 19 of IEC TC57. He is senior member of IEEE-PES and IEEE-SA. He is active in several working groups of the IEEE-PSRC (Power Engineering Society – Relay

Committee) and member of the PSRC main committee and the subcommittee H. He is international advisor to the board of the UCA international users group.

Rodney Hughes

Rod Hughes has over 30 years' experience in protection and automation systems. He has been the General Manager of one of the major relay vendors in Australia/New Zealand, Technical Director for development and marketing in Europe, Engineering Manager for a transmission utility in Australia and a State Manager and Technical Director in large multi-disciplined consultancies.

Rod is currently Convener of CIGRE Australia B5 Panel for Protection & Automation and Australian representative to the international Study Committee B5.

Rod has been a co-author of CIGRE Technical Brochure 326 "Implementation of IEC 61850" and has been involved in a number of other TBs as author or final editor.

Rod is convener of CIGRE Working Group B5.39 "Guidelines for documentation of digital substation automation systems".

Rod is now an independent consultant specialising in assisting organisations through the change management, business case, specification, implementation and training for IEC 61850 systems. Rod has presented many papers and provided various training courses from introduction to practitioner training in IEC 61850. Rod also owns the patent for the Operator & Test Interface unit for IEC 61850 systems