More than meets the eye

Beyond IEC 61850 as a pure communications standard

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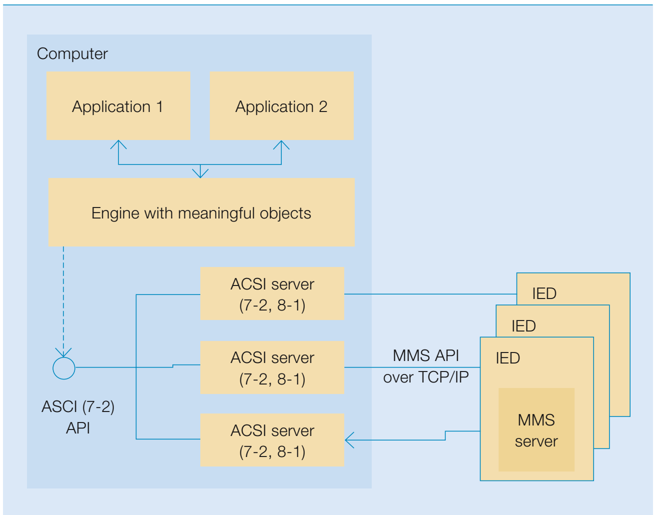
In a typical energy IT environment, how do you get several components and devices from different manufacturers to operate seamlessly together? The answer lies in a cost-effective standardized communication interface that enables open infrastructures and the interoperability of devices.

One such standard, IEC 61850, is regarded as an important international standard for substation automation systems because it defines the communication between devices in the substation, as well as the related system requirements and the underlying data model.

ABB Corporate Research is making use of these IEC 61850 features to provide plug and play technology for substation automation applications.

Electrical substations are complex distributed systems – containing heterogeneous primary equipment, such as switchgear, transformers or lines – and are controlled by Substation Automation Systems (SAS). An SAS is composed of all the electronic equipment[1] needed to continuously control, monitor, and protect the network. This equipment is interconnected and has to communicate at different levels in and outside the substation (eg, towards the network control centre). Traditionally, the engineering and configuration efforts for an SAS have been intensive. These efforts have also proven costly in that (a) customer delivery costs are driven by the missing standardized configuration description among devices from different vendors, and (b) product development costs are driven by the number of proprietary or semi-standard communications protocols that must be supported.

1 A simplified view of the architecture of a plug and play application based on IEC 61850. Numbers in brackets denote the corresponding part in the standard. Examples of applications include basic monitoring or control systems



Thanks to the recently adopted IEC 61850 standard [1] – and, in particular, two unique features of the standard – SAS engineering and configuration costs have been significantly reduced. These unique features include self-describing Intelligent Electronic Devices (IEDs)[2] at run-time (because of their data and communications service models), and a standardized substation configuration language (SCL).

These two features allow ABB to employ a plug and play[3] approach to substation automation applications to help alleviate costly project engineering for many customers.

The IEC 61850 standard

IEC 61850[4] is a substation automation communication standard. Its main objective is to enable seamless interoperability of IEDs (especially from different original equipment manufacturers) within the substation. It is divided into 10 parts, which circle around four major issues: a functional model of the substation automation application domain (Part 5), a data model for SAS (Part 7), communications protocols and their services (Parts 7, 8 and 9), and an XML based Substation Configuration description Language (SCL – Part 6) [2].

> Thanks to the substation automation communication standard IEC 61850, SAS engineering costs have been significantly reduced.

A model generally provides some information about a piece of equipment or a process. In substation communications, a model that lists the input and output data of a transformer, for example, is known as a data model and for each function, IEC 61850 has a data model. A data item has a name, which comprises three standardized parts namely, the Logical Node (LN), the data object and the attribute[5].

Since the IEC 61850 standard defines the entire data model in a text-and-table format, Unified Modelling Language (UML)[6] [3] has been used to develop a formal model [4,5] of it. Throughout the rest of this article, this is referred to as *the UML model*.

In a substation automation system, there are 2 types of data exchange: run-time application data exchange and (off-line) configuration data exchange. The run-time data exchange is enabled through communications services. IEC 61850 part 7-2 defines a set of abstract communication services (ACSI) that address the basic requirements for the process of exchanging information. These services can be implemented as an Application Programming Interface (API) specified in a given programming language, and/or services of the application layer of a given communications stack. Examples of this kind of exchange include reading the current position of a circuit breaker, or an operator command, or a protection function trip to change the breaker's position at run-time. These services and their implementation are the "how" of the data exchange.

The second type of data exchange concerns configuration data among all

Footnotes

1) In IEC 61850 talk, an SAS is usually composed of Intelligent Electronic Devices (IEDs) which are connected by a communications network.

2) Self-description of an IED means its ability to provide certain information such as process status information or configuration information of protection settings (the latter type of data is typically not available in previous SA communications standards).

3) A plug and play application means it can discover the functionality of one or more IEDs at runtime without any configuration required, and then generate a corresponding graphical user interface based on these findings.

4) ABB is very involved in the definition and maintenance of the IEC 61850 standard (several editors of the standard are employed by ABB), and as a result it is a leading vendor in that field. Today, this is vital as many new projects, especially in China and India, require its use.

5) The Logical Node, the data object and the attribute are illustrated by the example of a circuit breaker. The status of the circuit breaker – using IEC61850 terminology – has the name: XCBR.Pos.stVal. XCBR (the circuit breaker) is the logical node. Pos (switch position) is the data object and stVal (Intermediate state, on, off, bad state) is the attribute.

6) The de facto modelling standard in software engineering.

SA applications and devices. It is performed using XML (eXtensible Markup Language) files that follow the SCL[7] outlined in the standard. These XML files describe the configuration of IEDs in terms of functionality (eg, circuit breaker control, measurements and status values), communication addresses and means (eg, fast multicast messages, reporting), as well as the switch yard layout and its relation to the functions implemented in the IEDs.

Intelligent plug and play applications

In the following paragraphs, It is assumed an IED is fully compliant with the IEC 61850 standard. In other words, it should provide an ACSI-compliant interface to its data. Intelligent, and plug and play applications can rely on the interoperability features normalized by IEC 61850. The discovery and retrieval of actual values for process and configuration data is performed as follows:

1. Plug the computer with the running application into the IEC 61850 network.
2. Provide the IP address of the server residing within an IED. (This step is the only one not considered fully plug and play)
3. The application retrieves the variables using ACSI directory services.
4. The user interface of the application is auto-generated according to these variables and their semantics.
5. The application acquires current values for all variables of interest
6. If updated values of process data are needed, the application subscribes to adequate events.

Steps (2) to (6) can be repeated for as many servers as is needed. Because step (2) is not considered fully plug and play, a network scan can be performed to detect different servers – which respond on a predefined port – provided security mechanisms in each IED allow this.

1 shows the outline of a plug and play system architecture. The ACSI servers provide services as defined in Part 7-2 of the standard, and they allow services to be abstracted independently of their specific implementation. They also permit the "browsing" of variables, the retrieval and setting (where applicable) of certain values, and finally, updated process data through an eventing mechanism can be received. The engine is the "semantic" interface between ACSI and the application. It takes care of transforming MMS[8] variable names into meaningful objects according to Parts 7-4 and 7-3. The access rights – read, write, or read/write – are automatically identified for each data attribute. The engine is also responsible for catching any event providing live process data and then updating the corresponding values. An application, for instance a basic monitoring system, relies on the engine to acquire the servers' contents and to get and set values. As the type of data is clearly identified, the engine can provide views for process data (current values, analogue or digital), or parametrization (of protection functions). Furthermore, events can be logged and displayed to the user, and some can even be automatically interpreted as alarms.

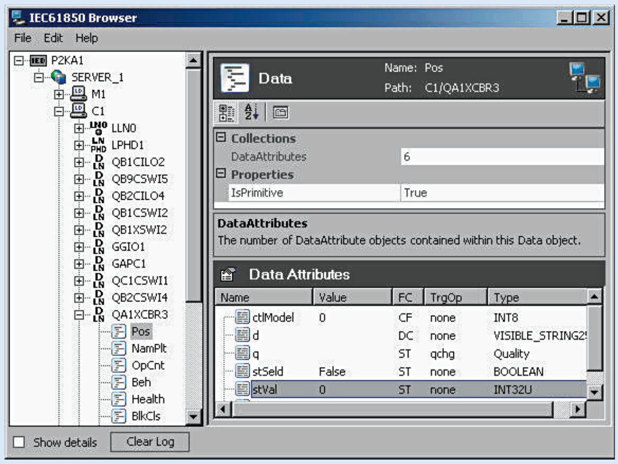
Key components of the plug and play architecture are becoming an integral part of existing ABB SAS products.

Some prototype applications[9], developed at ABB's corporate research center in Switzerland as part of the "Zero-Configuration Substation Monitoring System" project, are described briefly below.

A plug and play IEC 61850 browser

A screenshot of a plug and play IEC 61850 browser is shown in 2. A very basic monitoring system can be built using only the IP address(es) of the device(s). Equipped with this IP address, a user can access the contents of the IED automatically and autonomously, ie, without prior configuration of the software. In the example in 2, the contents of the Logical Node *QA1XCBR3* (reflecting the information of a circuit breaker) is shown together with its data object *Pos* (the position of the breaker) and the data attributes (with their names, types, values and other properties) belonging to that data object. None of these properties is hard-coded but is instead generated from the semantic information the application possesses, and which comes from the formal data model expressed through the UML model.

2 An IEC 61850 browser: an application that needs no configuration, but can discover the contents of an IED, analyze it semantically and auto-generate the display.



A plug and play IED configuration comparator.
Another immediate application built on the top of the engine is a plug and play IED configuration comparator. It compares the actual contents of an IED with its configuration, as described in the corresponding SCL file. The usefulness of this tool is particulary evident during commissioning or maintenance, when the engineer needs to verify that the actual IED configuration matches that provided by the corresponding SCL file.

A plug and play IED configuration generator.
Normally, SCL files are generated by the engineering tool. However, it is possible to generate an SCL file automatically. This is particularly useful during retrofit as most substation automation systems do not have an SCL file describing them (or if one does exist, it may be outdated). The generated SCL file can then be imported into the engineering tool for further processing, thereby avoiding tedious and error-prone work.

The example applications described above illustrate the possibility of building plug and play applications based on the self-describing capability of IEDs at run time, using only the IP address (or a range of them) as input. However, there are limitations, from a system perspective, on what can be done using the purely data model and ACSI services (as defined in Part 7 of the standard), since they focus only on individual IEDs. As a result, it is impossible to bind the discovered functions (ie, logical nodes) to primary equipment automatically or to deduce the substation layout, or even to analyze the inter-device communication network. In other words, given solely the IP address (or their range), only a very basic monitoring system focusing on individual IEDs can be built.

IEC 61850 is much more than just a communications standard as it also defines a data model and services to operate on that data.

To extend the capabilities of the monitoring system, an additional complete and up-to-date SCL file is required if the substation automation system, as a whole, is to be understood. If, however, an application requires a user to provide such an SCL file, this application is no longer considered fully plug and play. A possible solution might be to host the extra SCL file at a predefined address on a gateway. If that were the case, then the application described below would be possible.

A plug and play (basic) substation monitoring system.
The IEC 61850 browser described above can discover a substation automation configuration of one or more IEDs. Thanks to the data model defined in the standard, status and measurement data points are easily identified, and therefore a graphical user interface can be built to automatically display all process (status and measurement) data. Additionally, subscription to an eventing service that provides updated values can be done automatically. Furthermore, if an SCL file with switch yard description (ie, a substation section) is provided, a simple, single-line diagram incorporating process data can be built and displayed.

Conclusion

Despite its name, IEC 61850 is much more than just a communications standard as it also defines a data model and services to operate on those data. ABB's Corporate Research has exploited these features to develop the underlying technology that enables plug and play applications (for instance, deducing IED configuration automatically). Of course, very complex systems such as a SCADA can never be fully plug and play and would still require some engineering. However, the engineering required can be simplified using the proposed approaches, resulting in reduced factory acceptance tests, commissioning time, and maintenance.

Key components of the plug and play architecture are becoming an integral part of existing ABB SAS products. This, together with the complexity and the increasing importance of IEC 61850, has triggered the joint development of tools across ABB.

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ABB publications about the IEC 61850 standard can be accessed at: http://www.abb.com/cawp/seitp202/C1256A8C00499292C1256D4100388F27.aspx

Footnotes

7) The SCL defines the interrelationship of the substation equipment to each other and to the substation itself.

8) Manufacturing Message Specification: ISO 9506-1 and ISO 9506-2: Industrial automation systems – Manufacturing Message Specification; first edition, 2000-08-15

9) Some of these applications are currently in the process of being transferred to ABB's Business Units for product integration.

References

[1] IEC 61850: Communications Networks and Systems in Substations, International Standard, 2003.
[2] O. Preiss and A. Wegmann, "Towards a Composition Model Problem Based on IEC61850", The Journal of Systems and Software, Vol. 65/3, Elsevier Science, 2003, pp. 227–236.
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[4] T. Kostic and O. Preiss, "UML model of the IEC 61850 (v6, May 2004) and the data mappings between CIM 10 and IEC 61850". Not yet published (contact authors).
[5] T. Kostic, O. Preiss, C. Frei, "Understanding and Using the IEC 61850: A Case for Meta-Modelling," Elsevier Journal of Computer Standards & Interfaces, vol. 27/6, pp. 679–695, 2005.