A testing environment

ABB's comprehensive suite of software testing and commissioning tools for substation automation systems

TETSUJI MAEDA – The testing and commissioning of IEC 61850-based substation automation systems introduce new challenges and demands for advanced software applications. ABB recognized this at a very early stage of the introduction of IEC 61850 and redesigned the engineering and testing tool landscape to serve these purposes.

The IEC 61850 standard is built mainly on known technologies such as extensible markup language (XML), Ethernet, manufacturing messaging specification (MMS) and transmission control protocol/Internet protocol (TCP/IP), each of which have a number of well established software tools to handle them. Why then was it initially quite challenging to deal with IEC 61850-based systems?

The crux of the matter lies in the approach taken. IEC 61850 seamlessly combines the underlying technology components and application aspects from an integral system point of view. Existing tools, however, were designed to focus on specialized single tasks, for example communication analysis, and leave out any substation automation application aspects, and are therefore no longer capable of addressing today's challenges. To overcome this problem, it was evident a new generation of software tools to efficiently manage and support the IEC 61850 system integration process was needed.

ABB's approach, taken during the initial phase of the introduction of IEC 61850, was to take the existing expert tools and identify clear functional gaps in them. This information was then used to develop (and afterwards continuously improve) a comprehensive suite of software testing tools for communication, and protection and control application specialists in the field of substation automation.

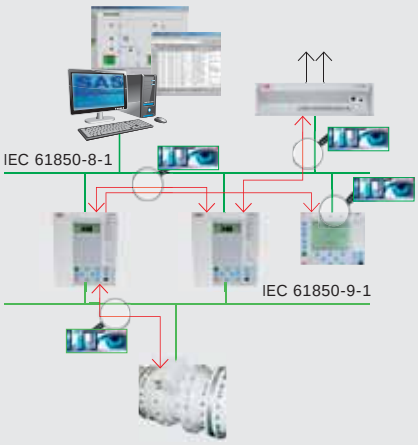
ABB developed the Integrated Testing Toolbox, a software tool suite used to manage and support the IEC 61850 system integration process and which has proven invaluable in many turnkey SA projects.

With the benefit of active participation in the IEC 61850 standardization group on its side combined with its in-depth knowledge and experience in designing and building substation automation (SA) sys-

1 Typical contents of a system configuration description (SCD) file

- Description of complete substation topology and primary equipment
- All protection and control devices (servers), and station level automation system (clients) including the standardized data models of their functionality
- All communication addresses
- Complete horizontal and vertical data-flow within the system
- Relationship between SA functionality and the primary equipment

2 Application areas for analytical and diagnostic tools



3 Typical features of a diagnosis and analysis tool

- The use of project specific data (SCD file) for configuration
- Establishing an online communication connection to the IEDs using either static or dynamic configured data sets and control blocks for reports
- Visualizing the health of the running system
- Checking data consistencies and configuration revisions against the SCD file
- Analyzing and verifying running applications
- Decoding Ethernet traffic to the substation automation (SA) domain language based on the SCD file
- Showing functional (system-oriented) or product-oriented addressing of logged data

tems, ABB developed the Integrated Testing Toolbox (ITT), a tool suite which has proven invaluable in over 900 turnkey SA projects delivered by the company.

From the very beginning, ABB's approach was to build a tool suite that would hide the complexity of the technology components IEC 61850 is built on and focus on displaying application relevant data only. While having an in-depth knowledge of the technologies was necessary to achieve this, the complexity lay in creating the interfaces that would enable the application and display layer of the testing tool to be tailored to project specific configuration data.

Substation configuration language (SCL)

One of the greatest achievements of the IEC 61850 standard and one of the things that differentiates it from other communication standards was the introduction of the substation configuration language (SCL). SCL makes it possible to create files that are used for the exchange of configuration data (eg, standardized object models and data flow configurations of devices in a system) between engineering tools. Several file types have been defined in IEC 61850, and the content of each type depends on the role of a specific tool (e.g., system configuration tool or device configuration tool) that it is created for and the different evolution phases of the system integration process.

The system configuration description (SCD) file is one such file type, and is defined as the master document of a complete SA system ➔ 1. For creation and maintenance, an IEC 61850 system configuration tool is required.

From the system point of view, the interfaces for each device (client or server) connected to the system are described in this file. This makes the complete SCD file the central part of the IEC 61850 system documentation, which makes it interesting to be used for all future activities performed on the SA system, such as testing, maintenance and extensions. The engineer no longer needs to worry about error-prone manual configuration of the testing and analysis tool environment; all he has to do is simply import the project-specific SCD file into the testing tool. This in turn focuses the effort to where it is most needed, on functional diagnosis and analysis of the running applications.

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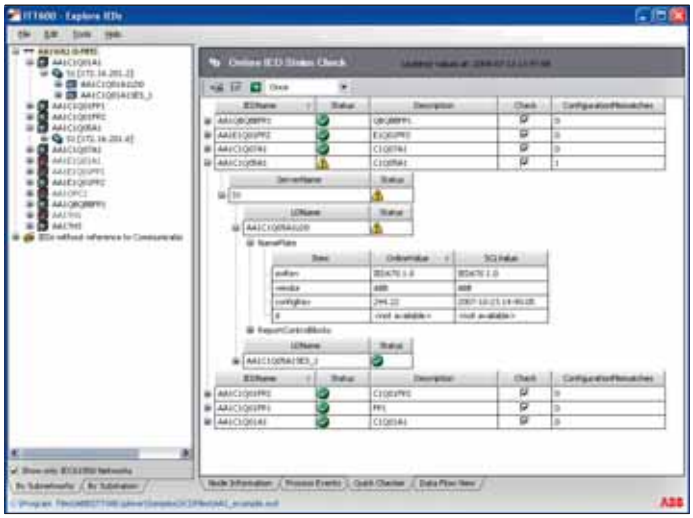
Conformance testing

One very important aspect of IEC 61850 system integration is the selection of standard complaint intelligent electronic devices (IEDs). Compliant in the sense that all selected IEDs have been tested to ensure that they conform to the IEC 61850 standard and are officially certified by a test center which itself is accredited by the UCA international users group. This certification covers the verification of the data model, the standardized documentation and a black-box test of all the communication services the IED supports. The conformance test gives a minimum guarantee that the selected IEDs will interoperate with other certified devices if they are configured and loaded correctly within the system. This prerequisite relieves the testing tools from research and development related bits and bytes analysis even more.

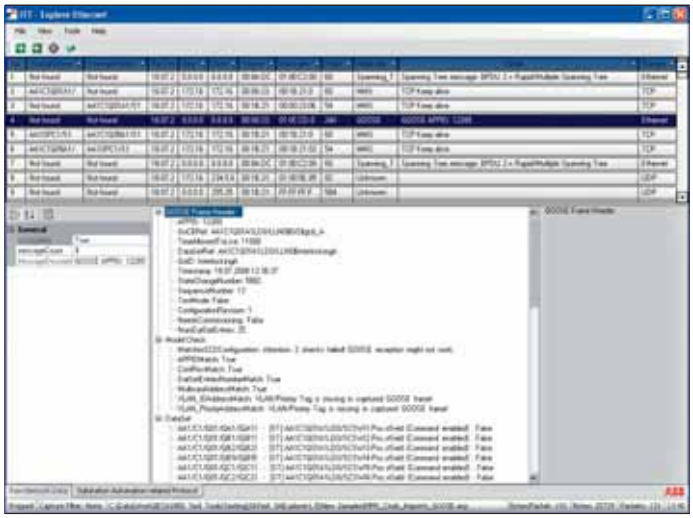
Revealing inconsistencies

There are often situations, specifically during the testing and commissioning phase of an IEC 61850 based system, where temporary inconsistencies due to stepwise integration, the configuration of systems parts or simply human error result in a situation where distributed functions do not interoperate. Debugging can be very time consuming and often requires expert know-how, which is not always available. To handle such situations ABB has developed a tool called the ITT600 SA Explorer. It simplifies the diagnosis and troubleshooting of IEC 61850-based SA systems by combining a set of

4 Consistency check – comparison of an SCD file with online data using ITT600



5 Decoding the horizontal Ethernet traffic with an IEC 61850 analyzer (ITT600)



powerful online diagnostic tools with built-in intelligence to interpret IEC 61850 data. Typical application areas within an SA system where the ITT600 SA Explorer can be of great value is shown in ➔ 2, while typical features of a diagnostic and analytical tool are listed in ➔ 3.

Narrowing down a problem source basically requires some quick consistency checks ➔ 4. One such check that can immediately reveal inconsistencies involves comparing the correct offline configuration with the online communication – as it actually is – world.

The comprehensive decoding by ABB's ITT600 SA Explorer of an IEC 61850 generic object oriented substation event (GOOSE) message, which is used for horizontal real-time communication between multiple IEDs, is illustrated in ➔ 5. The on-screen display of clear text protocol and application information, with the mapping of it to the IEC 61850 SCD file in the background, gives an excellent view of the corresponding online Ethernet traffic. Additional checks on the IEC 61850 object model reveal potential sources of interoperability problems.

Tools visualize applications

Another way of supporting the testing of distributed functions is shown in ➔ 6. Here the GOOSE messages from multiple IEDs can be displayed along a common timeline, making it easy to follow the interaction of various applications, such as interlocking or double command blocking.

Tools support processes

To support the ABB project execution process the IEC 61850 simulation tool out of the ITT tool suite has proven to be very useful. Specifically during engineering phases or factory acceptance tests when not all system components are physically available but nevertheless application tests must proceed, simulation of non-existing devices is essential for efficient workflows.

The IEC 61850 simulation tool can be connected either to the system bus or directly to an IED ➔ 7. The SCD file that has been created and used during the engineering process of the specific SA system, and which is now part of the common system documentation any engineer should have available when he goes on site, is then loaded into the tool. In both cases the tool could simulate one or more user selected clients/servers based on the interface description extracted from the SCD file. If the SCD file is missing or incomplete, then the engineering and configuration work has to be completed first. Based on this simulation, application tests on real system components can be performed. If the process bus or additional injection hardware is used, then closed loop testing of an IED is possible. Typical features of a simulation tool are summarized in ➔ 8.

Various substation automation projects have shown that the most obvious and common application for using GOOSE messages is interlocking. The horizontal GOOSE service uses publisher-subscriber communication, which corresponds to

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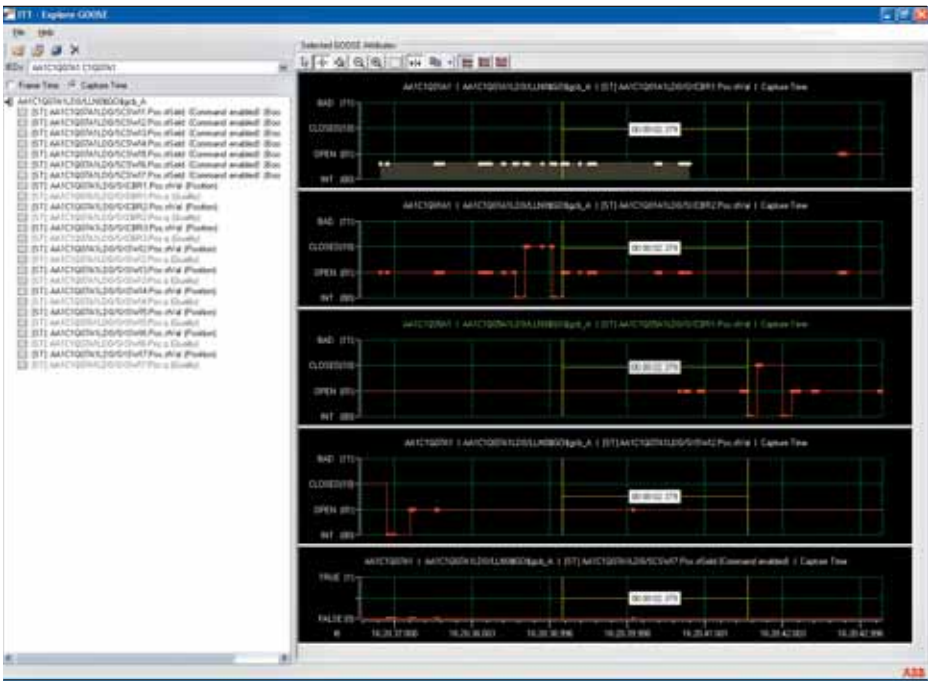
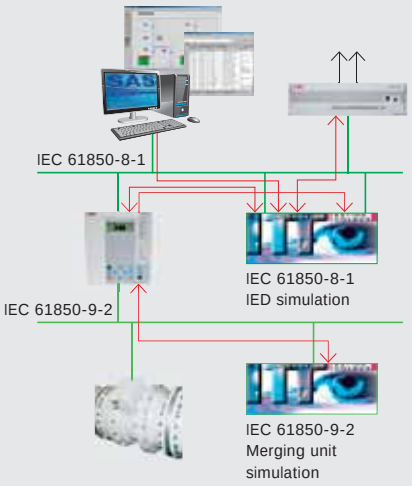
6 Horizontal GOOSE communication between multiple IEDs with ITT600



7 Application areas for simulation tools



vertical server-client communication. In a situation when a specific IED "publishes" data for interlocking, eg, switch positions have failed (and therefore the IED must be taken out of service or disconnected from the communication bus), the subscribers of the now missing data on the bus must be operated in an interlock-override mode. This is because applications running on the IEDs usually refuse operations with obsolete data that have not been refreshed in time by the publisher. Maintenance concepts for such situations must be considered in order to ensure that the remaining healthy or unaffected parts of the system continue to work undisturbed. This type of situation can typically occur during the testing and commissioning phase where the sequential adding of bays – including their control and protection IEDs – to an energized system should not lead to major re-engineering and reloading of the configuration.

A growing trend

The IEC 61850 standard is complex and cannot be applied without any significant software support. The degrees of freedom and new possibilities that it offers, combined with varying levels of IEC 61850 integration, both in the configuration tools and IEDs from different suppliers, emphasize the challenge even the more.

There is a strong trend toward the use of more modern communication technology to distribute critical data and this demands more advanced integration and verification processes.

Evidently, the strong trend toward the use of more modern communication technology to distribute mission critical data demands very advanced integration and verification processes. To manage these challenges, engineering, testing and commissioning tools have been developed which incorporate all the possibilities offered by the IEC 61850 standard. They have been proven to facilitate and ensure the high standards of ABB's project execution.

8 Typical features of a simulation tool

- Uses project specific data (SCD file) for configuration
- An IED specific configuration can be extracted from the SCD file
- The consistent simulation of selected IEDs
- Real life simulation of communication services
- Horizontal communication – repeated sending of GOOSE messages and cyclic sending of sampled values
- Vertical communication – spontaneous sending of reports
- Setting any data configured in the IEDs selected for simulation
- Tailored scripts for the simulation of simple applications, such as control applications double command blocking

Note: Receiving IEDs and clients cannot see any difference between simulated and real data on the bus

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