SUBSTATION AUTOMATION SYSTEMS CURRENT CHALLENGES AND FUTURE REQUIREMENTS - THE INPACT PROJECT PERSPECTIVE

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ABSTRACT

IEC 61850 has been widely accepted as the communication networks and systems standard to be used within Substations and has introduced well know benefits. However, there is still a significant improvement opportunity regarding systems engineering efforts, which will be even more significant as the DA trend grows, together with the need to assure an integrated automation approach.

In this paper the authors (i) discuss current constraints of the SAS engineering processes, (ii) present the InPACT project objectives and strategy to develop a next generation tooling environment, (iii) describe the resulting engineering toolset features and (iv) present the future challenges of the automation systems.

INTRODUCTION

Current Substation Automation Systems (SAS), based on distributed architectures supported by the IEC 61850 standard provide a large number of benefits in addition to the traditional features such as control, protection, monitoring, automation and metering. These benefits include project cost reduction, organizational effectiveness improvement, and new technical features.

However, new constraints also result from the application of first generation IEC 61850 systems, with a more complex base technology and higher dependence on manufacturer support. Considering the continuous pressure to improve performance indicators, it becomes more difficult to increase engineering productivity and to simplify systems management and operation without a higher-level and open engineering ecosystem.

In this perspective, the configurability of devices and systems and the maturity of engineering tools and processes is one of the major constraints to further productivity increase and a key issue for the future of power systems automation. There is, thus, a clear drive for integrated solutions supported by engineering tools throughout the entire SAS process life cycle.

IEC 61850 OVERVIEW

The IEC 61850 has been widely accepted by the utility industry as the communication networks and systems standard to be used within substations and has introduced well known benefits such as interoperability, free configuration, simple architecture and overall cost savings.

By using an object-oriented and hierarchical data model and the Substation Configuration Language (SCL), IEC 61850 proposes a new approach in the methods for specifying, implementing and testing SAS.

The SCL is supported in a XML based file format, containing the description of devices and the information models, which can be used to exchange configuration information between tools of different manufacturers in a compatible way within and between different SAS life-cycle phases.

SUBSTATION AUTOMATION SYSTEMS IN THE PORTUGUESE UTILITY

EDP Distribuição (EDPD) is EDP Group's company operating in the regulated distribution and supply businesses in Portugal.

Telecontrol and automation drivers

Over the last thirty years EDPD developed a telecontrol and automation strategy aligned with business goals, focused on the Operational Expenditure (OPEX) reduction and Quality of Service (QoS) improvement [1], in the end of 2009 EDPD assets included almost 400 substations.

Since the introduction of telecontrol technology in the eighties until the substation automation, first supported in RTUs (Remote Terminal Units) and later, with the adoption of a standard Substation Design approach, in IED-based integrated systems, the complexity and features of the solutions has deeply increased. In 2006, EDPD started the first experiences with the SAS operating according to standard IEC 61850 [2] and since then, EDPD adopted these type of solution for new substations or whenever refurbishments are made to both RTU and protection system. Currently, EDPD is reviewing the system specification in order to integrate the IEC 61850 aspects.

In a retrospective analysis, we find that in the last decade, the great gains have mainly resulted from the wiring schemes simplification, systems convergence (protection, control and monitoring), more efficient and reliable operation and QoS improvement. However, in the Substation domain, there is still a significant improvement opportunity regarding systems engineering efforts, which will be even more significant as the Distribution Automation (DA) trend grows together with the need to assure an integrated automation approach, and therefore EDPD is reviewing the system specification in order to integrate the IEC 61850 aspects.

SAS current constraints

Considering the SAS life cycle: (i) Specification; (ii) Design; (iii) Configuration; (iv) Testing and (v) Operation and Maintenance, there are several aspects which present constrains to further productivity increase.

Fig. 1. SAS life cycle.

Specification

The traditional approach regarding SAS specification, focused in the identification of technical, functional and performance requirements in natural language and without detailed requirements with regard to IEC 61850, as opposed to comprehensive model in formal languages (IEC 61850 SCL being a possible candidate), that describes the substation specification with a reduced level of ambiguity and that could be used directly as input to the subsequent SAS phases.

Design

The selection of devices can be freely left to the system integrator or it can be limited by a pre-selection of devices homologated by the utility. In the EDPD case the accepted generic system physical and logical architectures are pre-established, including generic devices and communication equipment. During the design phase the specific devices are identified, and their applications and system roles defined. User training, regarding protection, automation and communications can then be planned.

Configuration

During system configuration, the logical communication relationships between IEDs are defined and the functions of the system specification are implemented. Depending on selected technology, use of different engineering tools to configure different devices or even functions within devices is usually required.

Testing

Testing activities, with the purpose to verify if the SAS is in conformance with the functional, technical and performance specification and that the SAS operates as intended, involve the type tests, the factory acceptance tests and the site acceptance tests. These acceptance tests are significantly time-consuming tasks, which could be automated if there was a strong agreement between functional requirements and implementations and if adequate engineering tools were available.

Operation and Maintenance (O&M)

The set of systems in operation in EDPD is constituted by several generations of equipments supported on different technologies and using distinct engineering tools, which leads to an increased dependence on manufacturer support. Documentation and visualization is also a constraint for O&M. For example, with copper wiring being replaced by more flexible logical connections, the electrical CAD systems must be replaced by power signalling engineering tools and diagrams.

New domains

With the introduction of process bus architectures, systems convergence trends, widespread Ethernet/IP networks, infrastructure security concerns, new automation or automation-related functions, DA expansion and the integration of advanced metering infrastructures, systems management will be even more comprehensive and complex, thus scaling current engineering constraints.

It is quite clear that, besides the investment in IEC 61850 know-how and in communication technologies, the utilities should get the appropriate engineering tools, considering their importance during all the system life cycle phases.

THE INPACT PROJECT

Objectives

To tackle some of the constraints identified in the EDPD case, Efacec, a global product vendor and system integrator, led the InPACT project (Integrated Engineering Tools for Protection, Automation and Control Systems) together with EDPD and University of Minho from 2008 to 2010.

The major objective is to introduce a next generation integrated toolset that: (i) provides increased flexibility for system configuration and multi-vendor integration; (ii) simplifies systems engineering; (iii) increases engineering productivity; (iv) supports the systems throughout the life cycle and (v) establishes the foundation for future toolset evolution.

Strategy

Within the identified global requirements for engineering tools in this domain [2] and the analysis of the substation automation industry state-of-the-art, two alternative strategies could be employed: (i) a design-based approach or (ii) an implementation based approach.

Design-based approach

Fundamentally identified as system and model-based approach, would centre the engineering toolset on a formal system language capable of describing all system components including communications, logics, devices, device functions and HMI. Such a language, a superset of the IEC 61850 SCL, would be suitable for description of the specification, design or full implementation (hence inherent system documentation), depending on the level of detail in the definitions.

This approach would be extremely productive in the general case since (i) the engineers would focus on the high-level design and visual language [2] instead of the implementation details, (ii) models could be used as unambiguous engineering artefacts between all actors and phases of the engineering process and (iii) most of the implementation and testing could be automated.

Implementation-based approach

A device-oriented approach that would unify the device implementation models and boost productivity by delivering an advanced GUI engineering environment capable of systematically automating routine engineering tasks.

Adopted strategy

In the context of the InPACT project the second strategy was adopted, given that: (i) the available SCL format was not suitable for whole system engineering (even today it still lacks in scope and in industry application [3]), which would inevitably render the model-based approach to a vendor-specific solution (at least in the project time-frame); (ii) the second approach would render benefits during early stages of the project, as it is more suitable for iterative tool development; and (iii) adopting the second approach, while leaving room for applying the first strategy after the project is completed and the industry matures, would assure a high productivity environment without compromising the project goals and future evolution of the toolset.

THE ENGINEERING TOOLSET

Architecture and Features

The resulting engineering toolset is currently in use in several projects worldwide by different engineering teams. It is mainly focused in the configuration and O&M phases, while providing some design-oriented features such as template-based engineering and reusable elements such as libraries.

One of the major distinguishing characteristic is that all features are integrated in the same multi-window/layout environment (without employing any external tools) and share a common project and build system independently of the engineering activity to be performed. The resulting unified interface shares common access paradigms and metaphors that not only facilitates sharing of data between different engineering roles, often performed by different people, but also greatly reduces the user learning curve.

Given the modular supporting framework, tool components are also reused. An example is the advanced 2D mimic designer which is used for drawing both IED LCD screens or sophisticated SCADA screens, hence sharing editing GUI, simulation GUI and definition of symbol libraries.

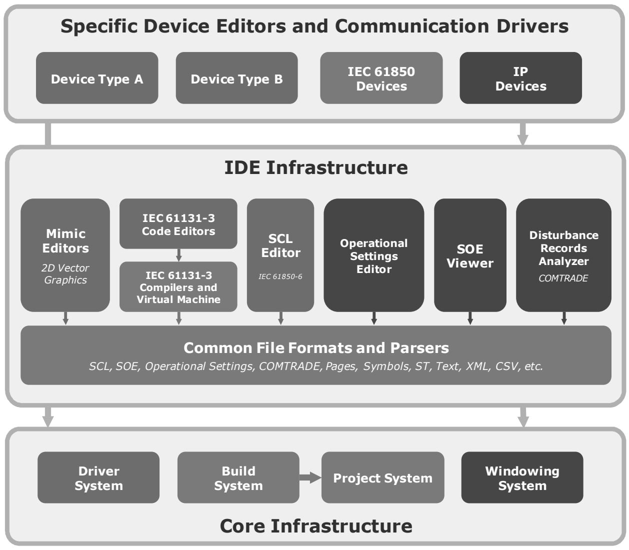

Fig. 2. Tool architecture.

Tab. I. Summary of features

Feature Group		Feature
Supported IEDs		Efacec Station controllers and local SCADA
		Efacec bay-level IEDs (controllers and relays)
		Third-party IEC 61850 devices
		Networking equipment or other generic IP devices
Configuration Settings	**Common Features**	System and library projects
		Reusable IED templates (full configuration)
		Reusable automation objects (including logic, GUI and data)
		Model validation and comparison tools
		Versioning and revision control system integration
	2D Mimic Designer	State-of-art 2D editor including user-defined compounded symbols and animations
		SVG import tools
		Multi-level symbol libraries
	IEC 61131-3	Code editors and compilers
		Standard and user-defined function block libraries
In-tool Simulation		Mimics
		IEC 61131-3 programs
IEC 61850 SCL		SCL import/export (ICD, CID, SCD)
		SCL validator
		SCL communication and data model editors
Operational Settings		Editor, import/export and comparison tools
Plug-and-play device monitoring		Data/event monitoring and control execution
		Network scanner and device identification.
		Automated or manual data records (SOE, COMTRADE, etc.) extraction
		Data record analysis
		Configuration and operational settings deployment and extraction
		System control panel for integrated system monitoring and management

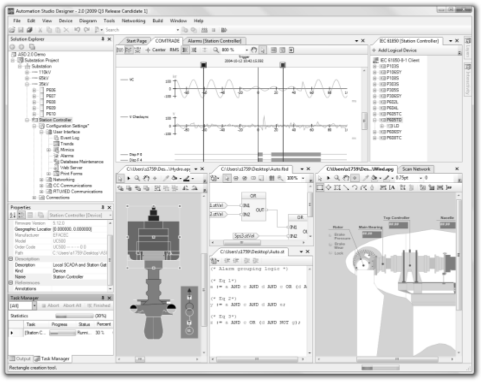

Fig. 3. Screen-shot of the engineering environment.

Role in the IEC 61850 Framework

The toolset is an IEC 61850 device tool, but also a system communication configuration tool fully capable of representing, holding and modifying third-party device models. It can be used for iteratively importing and exporting/merging SCL files, hence interoperable with other device tools or system tools (fig. 4).

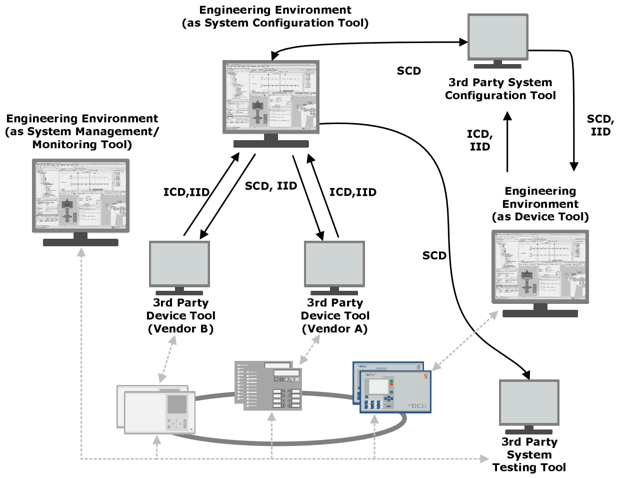

Fig. 4. Application of the IEC 61850 engineering process with the toolset.

Engineering Processes

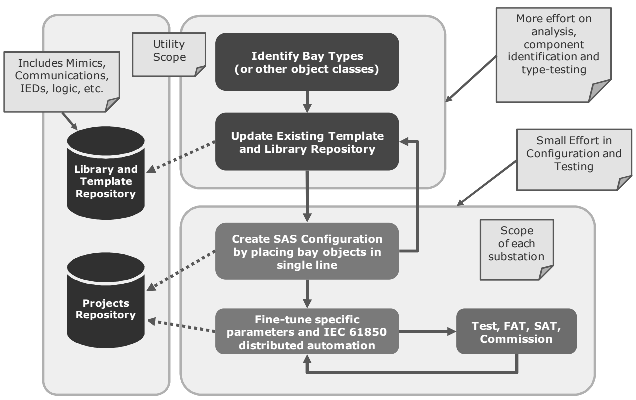

Fig. 5. Template-based engineering process workflow.

The toolset is suitable for different engineering processes and the choice of adequate process dependents on both project requirements and characteristics of the engineering tool. The most productive processes are usually more design intensive and template-based, particularly if several systems are foreseen, where design may be reused between all systems (fig. 5).

CONCLUSIONS AND FUTURE OUTLOOK

IEC 61850 has been a major step forward regarding engineering interoperability. The model-driven and system-oriented approach, together with the SCL exchange format, allows significant efficiency improvements with today's technology.

Nevertheless the IEC 61850 full potential in this domain is yet to be attained by current product implementations, which leaves room for significant improvement. Together with the enhancement of the standard itself (edition 2 and work in progress such as logics integration, UML modelling or CIM integration), it is expected that significant improvements in technology will be made available in the near future.

Regarding engineering processes, the proprietary and point-based approaches must be replaced by open and model-based engineering together with advanced and interoperable tool support. Methods and tools must be consistently extended to the specification and design as well as testing, including functional testing. Industry efforts, namely under the IEC, CIGRE and other bodies, are currently being employed in this direction.

Considering the continuous pressure to improve financial performance, customer service and organizational effectiveness, and the future requirements of the automation systems, to be prepared to pursuit an integrated approach, the utilities must promote and adopt solutions based on approved international standards, use integrated powerful engineering tools and benefit from the new communications services availability, in order to guarantee integrity and consistency throughout the whole automation system's life cycle.

As automation is extended from the substation to the whole grid, the issue of global engineering and engineering interoperability becomes critical for the cost-effective Smart Grid.

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