TOWARD AN AUTO-CONFIGURATION PROCESS LEVERAGING THE IEC 61850 STANDARD

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1. INTRODUCTION

Substation Automation has changed a lot during the last years, with IEC 61850 becoming the standard communication backbone interconnecting the different protection relays, meters, bay controllers, gateways and human-machine interfaces. The volume of data has been progressively increasing in order to bring new benefits to the user in term of operation and maintenance by eliminating the automation islands. This was initially happening within a substation but is being generalized between a substation and the rest of the grid elements (substations, generators, control centers, asset management centers). Efficient design and management of “systems of systems” lifecycles is one the coming smart grid challenges.

System engineering is at the basis of this design and management. It is typically composed of architecture design, database configuration and functional tests activities [1]. System engineering is still very much a manual process relying on people’s experience. System evolutions, linked to a change of the primary process (like adding a feeder) or a software version (fixing bug or adding new features), represent a specific engineering challenge today to optimize the process availability while guaranteeing the solution security. Increase of the system size and volume of data exchanged ask for more engineering, it also increases the probability for a system changes and thus further engineering.

In addition to these phenomena, the cost of hardware (IED – Intelligent Electronic Devices or IT – Information Technology) is regularly decreasing for a given function or performance. As a result the proportion of engineering cost vs. the total project cost might rise dramatically if nothing is done. Even more important are the lead times and possible quality issues linked to the manipulation of a lot of data. Engineering Automation is one of the solutions currently emerging in order to address these concerns, the auto-configuration being a part of the overall plug & play process. IEC 61850 is a key technology to achieve this goal, using the data semantic capability of the standard and that is currently under-utilized. The experience in substation automation system is the other ingredient for this change, capitalizing expert rules that have progressively been assimilated.

This paper shows a series of examples that have been developed in this direction, highlighting as well the possible extensions of the standard to foster interoperability of future solutions.

2. SYSTEM SPECIFICATION DESCRIPTION (SSD) AUTOMATIC PRODUCTION

a. Problem to be solved

Substation Automation requirement usually contains a Single Line Diagram (SLD). SLD has been often created by a different team than the one producing the Substation Automation requirement. This is obvious in the case of retrofit of the protection and control system, since the lifetime of the primary devices (switchgear and transformers) is twice the one of the IEDs controlling them.

The traditional engineering process is to manually re-enter the information contained in the SLD into the system databases, i.e. the interconnection of a series of busbar, circuit breakers, transformers, etc. through the graphical analysis of the SLD by an operator. This will populate the human-machine interface screens definition as well as the various IED interface and automation schemes (see the section of Fast Load Shedding for an example of automation using such topology information).

The IEC 61850 standard has defined the concept of SSD, standing for System Specification Description. The SSD is an XML file containing a formal description of the user functional requirements, irrespective of the technical solution that will be implemented: substation topology, as well as protection and control features of the installation. The SSD can be manually created, somehow reproducing the traditional process described above. The purpose of this section is to show how to automatically generate the substation topology part.

b. Solution principles

The solution is relying on the pattern recognition technology, converting a SLD graphical image into an XML file in line with the IEC 61850 standard [2]. The Figure 1 summarizes the key steps.

The first phase is a learning one for the different types of patterns of the picture - the operator will for instance select the representation of a circuit breaker and the software will associate it to the XCBR logical node. This is needed since the representations used in real systems is often not following international standard. It is expected that this phase will be automated as well.

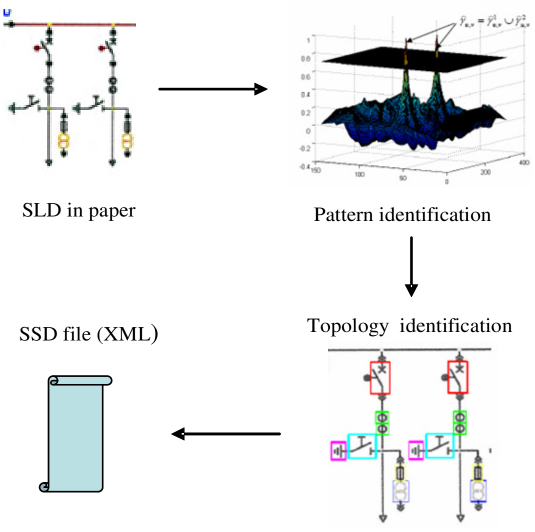

Figure 1: SSD Automatic Recognition Principles

The software will then recognize the different instances of each of the patterns in the picture. A comparison threshold enables to filter wrong associations that might occur when the original document's quality is poor. The detected pattern instances are automatically named, using a ruling mechanism pre-defined by the user. To improve this automated task some other naming options can be provided such as detecting the text close to the pattern or some surrounding configuration features (such as a transformer ratio) .

Next phase is to virtually eliminate from the SLD the patterns recognized in order to possibly highlights patterns still to be learned. Once done the software will detect the graphical connections between the patterns that symbolize the static topology. The SSD file will then be generated, formally converting the information present in the graphic into XML. The SSD might have to be extended with some information missing in the graphic, for instance the type of protection functions – this will be done using a specific editor.

The automatic creation of the SSD file is dividing by a factor at least 10 the traditional operations. It provides a file fully consistent with the graphical reference, avoiding the mistakes possibly introduced by the manual creation of SSD file.

3. FAST LOAD SHEDDING (FLS) AUTOMATION DESIGN

a. Problem to be solved

Any electrical system needs to insure the instantaneous balance between generation sources and loads. This classical request is often managed through the use of under-frequency protection relays that will load shed one of more feeders upon detection of a specific threshold. This local algorithm is unfortunately not sufficient when the system is made of one large industrial site first fed by limited in-house generation, since the system inertia requires a fastest response time. In such conditions sending the load shedding trip order shall be done within less than 80 ms after the occurrence of the issue compared to several hundred of ms in the classical scheme. Note that the venue of micro-grid is likely to generalize this requirement.

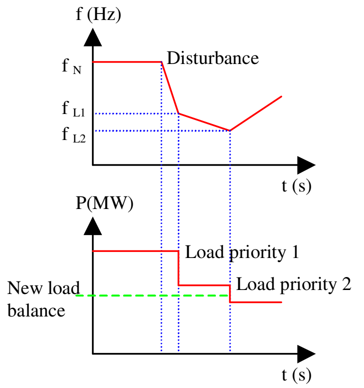

Figure 2: Conventional vs. Fast Load Shedding Schemes

The technical solution is to permanently anticipate the loads to be shed for each of the possible contingencies, such as the loss of a generator, or of a loss or saturation of an electrical connection between generation and load. Such "what if" calculations are computed permanently in order to pre-set load shedding schemes, and the occurrence of a fault the will operate the shedding mechanism. The scheme is centralized in a redundant computer or distributed between several IEDs depending on the overall system architecture.

This solution has been proven on several real projects. Until recently the engineering of the associated automation scheme was manual, typically identifying all possible combinations of electrical sub-networks balances in order to pre-program the reaction. The purpose of the next section is to explain how this has now became automatic, thus reducing the engineering cost, time and possible mistakes.

b. Solution principles

The solution is relying on the formal expression of the system static topology and on a series of electro-technical rules in order to automatically process the shedding orders when a fault is occurring. The static topology is automatically entered (see the above SSD section), and verified at commissioning time through simple activation or simulation of each process data. The electro-technical rules are checked at the product design stage, not at the project time. Modification of the electrical scheme requires a basic check, not the full combination of the different equations as per the conventional practices.

Rules are verifying the balance of generation per "active electrical group" and with regard to electro-technical and process constraints. An active electrical group represents the list of generators and loads interconnected at a given time; this is determined by the position of the switchgear elements. The electro-technical constraints identify the available spinning reserves and associated dynamics, the transformers capacities, the large motor start demands, etc. The process constraints look at the relative priority of the different loads, the maintenance constraints, etc.

c. The big picture

Extending the type of rules enables the execution of other topology-oriented automation. Examples include electrical interlocking (rules exclude the connection of a live line to earth for instance), voltage regulation of parallel transformers (rule is to minimize the reactive circulating current), voltage consistency of multiple feeders connected on the same busbar (rule is to have their value within a permitted error), etc.

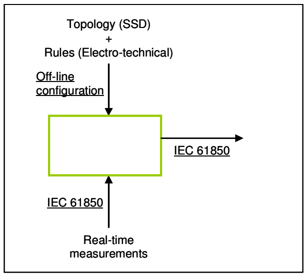

Figure 3: Software centric solutions

This "automatic automation design" is systematic and becomes very CPU intensive, rapidly growing with the size of the static topology. On the other hand the traditional electro-magnetic constraints existing on typical IED can be removed, with the replacement of process direct interface by Ethernet exchanges. As such the processing power of industrial PC can be fully leveraged to execute pure software products. Homologation of such software centric product (see figure 3) is certainly one of the coming evolutions in the substation automation environment.

In summary the engineering automation has an influence on the system architecture and on the product traditional business.

4. CONTROL CENTER AUTOMATION COORDINATION

a. Problem to be solved

Coordination with the control centre is another classical demand, for instance making sure that the position of a circuit breaker seen at control centre represents the right one. This is traditionally achieved by the exchange of an excel file, showing the address of each information exchanged. This file is typically derived from the control centre database and mapped on the substation automation system database (although other schemes are permitted). Version consistency between the two parties is checked manually.

This file is usually limited to the exchange of process information, i.e. measurements (analogue and binary) and control. However several other substation configuration data are available remotely: electrical static topology (used in the control centre), protection and recloser setting (computed centrally to insure coordination), alarm labels, graphical displays, etc.

The purpose of engineering automation here is to remove all manual mapping between the databases, to maximize the number of data references exchanged and to formally check the version consistency. This has been partly done with RTE, reducing by 40% the traditional substation database engineering costs.

b. Solution principles

In the case of RTE, specific conventions have been taken to define the file content. In addition to the traditional process I/O mapping, some of the protection, setting (such as overload) and alarm text have been defined. Figure 4 defines the general concept.

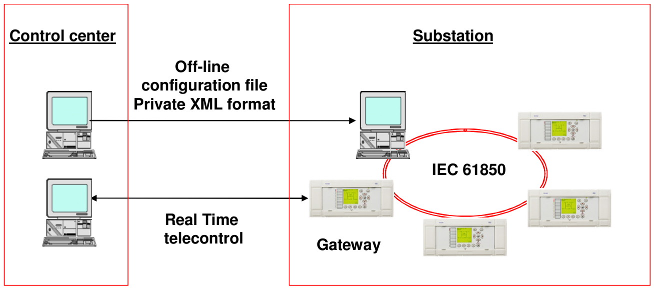

Figure 4: Control Center Coordination principle

A future generic solution would rely on several mechanisms:

- the coming IEC 61850 / CIM conversion, in order to have an automatic mapping of databases,
- the connection between the substation world and the EMS/DMS but also protection setting and cyber-security databases,
- the use of templates incorporating default automation schemes and process graphical displays approved at utility level,
- the synchronization mechanism, for instance relying on the SED (System Exchange Description) defined by the IEC 61850 edition 2.

5. GOOSE DATASET AUTOMATIC GENERATION

a. Problem to be solved

GOOSE are the messages exchanged between IED in order to contribute to a distributed automation between these devices. Defining the Goose is often a manual expert process, extracting the data needed for the distributed automation, defining the datasets (i.e. list of the data transported by a Goose message), assessing the VLAN to be used, creating the dataset into each IED, etc. This involves the use of different tools (IED engineering tools, system configurator) and is thus prone to error especially during evolution of the electrical or substation automation system.

The automation of such engineering has been accomplished using private conventions, since semantic is today missing in the standard for a totally open solution.

b. Solution principles

The principle is today to identify the series of elements that a device needs to send for its automation, define a dataset for pure binary information and a dataset for pure analogue information broadcasted to the network. Some refinements would be to multiply the number of dataset to integrate performance constraints; however this has not yet been proven as necessary.

The key element is to insure the consistency between data defined in an automation editor and IEC 61850 data referenced into an SCL file. Private conventions have yet to be done, waiting for an extension of the IEC 61850 standard. In such project the operator does not need to be an IEC 61850 expert but focuses his energy on the proper automation design

6. CONCLUSION

IEC 61850 standards is commonly seen as a way to communicate between devices. It is also a modeling language, capable to drastically simplify the engineering task, basically bringing some automation in the traditional process through database integration and database self-configuration. This results in a reduction of the engineering lead time, an enhanced inter-operability between equipment and an improvement in the system reliability and quality.

Extension of the standard, such as CIM vs. IEC 61850 conversion or integration of an automation language are important to further progress in that direction. Engineering tools will however hide the complexity to the user. Architecture evolutions can be expected to map the resulting products, with a growing number of software based product relying on a large amount of processing power.

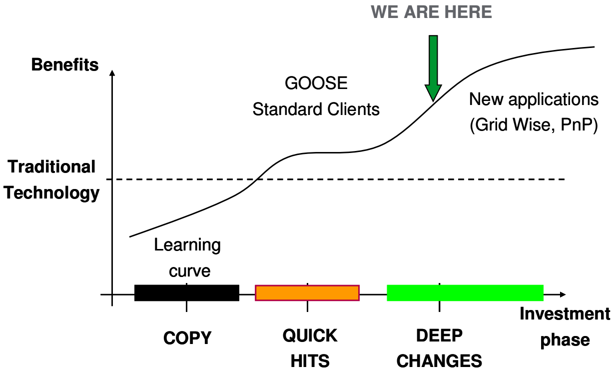

Figure 5: A new Era for IEC 61850 Business

This new IEC 61850 era (see figure 5) is relying on the capitalization of the experience of systems done since the last 20 years. It will form the basis of the coming Smart Grid schemes, providing solutions for the plug & play (PnP) requirements of these future architectures.

REFERENCES

[1] Luc Hossenlopp, 2010, “Challenges and Solutions for Substation Automation System Engineering”, PAC World Conference, June 2010

[2] IEC 61850-6 Standard