CONFIGURING A IEC 61850 BASED STANDARD AUTOMATION SYSTEM FOR A STANDARD HV/MV DISTRIBUTION SUBSTATION

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ABSTRACT

IEC 61850-6 defines an engineering approach to specify Substations Automation Systems (SAS) in which a Substation Specification Description (SSD) is first described by identifying the power devices and their required control, protection and other automation functions. These entities are mapped onto logical nodes, a 61850 language concept. After describing that Substation Specification, some files describing the Capabilities of Intelligent Electronic Devices (IED) are combined to provide a mapping of the required automation functions onto the IED, thus reaching a Substation Configuration Description (SCD) which must then be exported to the IED. While this engineering process is usually applied to any new Substation, the existence of a Standard design for HV/MV Distribution Substations supports a reusable development of that engineering process, drastically reducing the engineering work involved in each new Substation.

INTRODUCTION

IEC 61850 is a Standard covering both communication networks and systems in Substations. It includes a model for most power devices and control functions in a Substation, together with the definition of standard communication services to access the entities of the models, the Logical Nodes (LN).

While intended to provide interoperability between IEDs and between them and engineering tools, IEC 61850 does not support interchangeability. Manufacturers of IED keep their freedom to design their devices as they wish, provided the IED and their inner functions present a standard interface to the IEC 61850 communication services. One of the consequences of this intentional tradeoff is that a IED manufacturer has to provide a file describing the capabilities of its IED, the ICD, and it has also to be able to understand a configuration for its IED in the context of a complete Substation System, reading a SCD with some proprietary tool. This is why the configuration process for a IED is as presented in Fig.1: the SCD has to be built from both the SSD and from the vendor ICD, to be next returned to the IED proprietary configuration tool. This means that as a rule a generic configuration for an IED protecting and controlling a bay, for example, cannot be used for IED of different manufacturers, but it has always to be redone when another manufacturer is chosen.

This drawback is not a big deal if the configuration requirements and specifications differ from a bay to another or from a Substation to another.
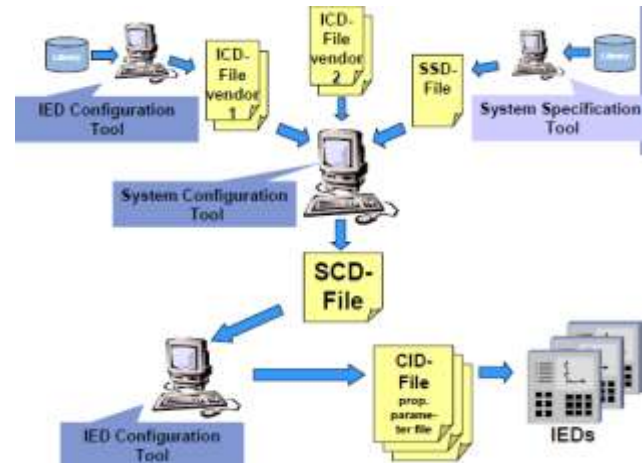

Figure 1: the engineering cycle with IEC 61950 [1]

However, some utilities have standardized the design of Substations, like EDP DISTRIBUIÇÃO has done for its HV/MV Substations, in order to get a common and detailed definition for the power devices, the Substations topology and particularly for the related protection and control functions. With that, an investment in mapping all the specifications to a single set of digital files, written in a standardized format such as the Substation Configuration Language (SCL) defined in IEC 61850-6, can represent added value to the utility after a few number of projects based on those specifications, since the files initially mapped can be easily imported and adapted. The development of a standard solution for the engineering process of a standard HV/MV Distribution Substation is what the authors report in this paper. The goal of this reusable development is to minimize the work involved in the engineering of each new Substation, exploiting the features of the IEC 61850 standard for that. The presented development is based on a System Specification tool independent from IED vendors [2], but the capability to successfully import and export files to the IED is guaranteed by the compliance of both this tool and the IED vendors proprietary tools with the IEC 61850-6 standard.

BUILDING THE SSD

According to IEC 61850-6, the first step in a top-down engineering approach to a SAS is the Description of the Substation components and topology, as well as of the related control, protection, monitoring, archive and measurement functions. This can be done in two steps as follows.

Substation modelling and single-line diagram

EDP DISTRIBUIÇÃO has developed a written specification for its HV/MV Distribution Substations, which defines a standard modular topology and a set of power equipments [3]. This design considers a maximum number of bays. A 61850 Substation Description which supports that maximum will comply with all foreseeable Substation instances. Most System configuration tools can easily perform such task and also provide a graphical diagram as in Fig. 2.
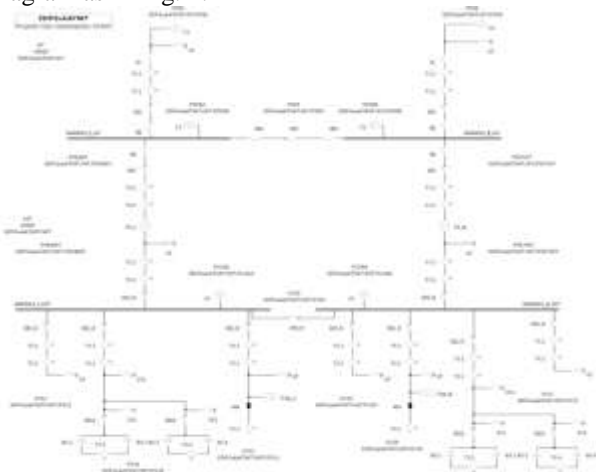

Figure 2: A Substation graphical description created by typical System Configuration tools

HV incoming line devices	Associated Logical Nodes

Figure 3. LN models fot the power devices of a standard HV incoming line

Equipments' interfaces to information exchanges are described by LN of 61850-7-4 [4]. Fig. 3 illustrates a result of this 61850 model, showing the standardized power devices for the HV incoming line bays and engineered with a suitable System configuration tool [2]. The first column in Fig. 3 represents the power equipments used in the bay, while the second column shows their associated LN,

each box representing a device function with the respective model of LN Classes presented in IEC 61850-7-4.

Standard control and protection functions

Together with the design of the HV/MV Substations and their power devices, EDP DISTRIBUIÇÃO has also standardized the related control and protection functions, as well as the monitoring, archive and measurement functions of its SAS. As for the power equipment functionality, most of these SAS specified functions also have a IEC 61850 representation by means of LN, as shown in Fig. 4.
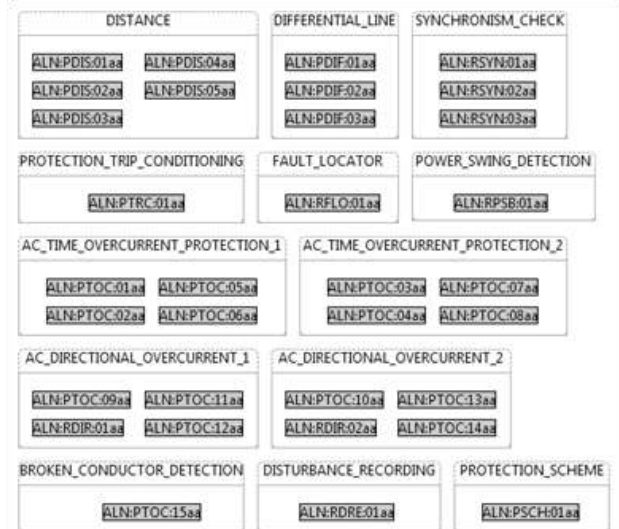

Figure.4: LN models for the standard protection and related functions of a HV incoming line

For example, in the HV incoming line bays, the full Distance protection specification is modeled by employing five instances of the L N class PDIS, one per step.

Although most of the SAS functions have straightforward LN models in the IEC 61850 SCL, some of them require a thoughtful consideration and a few of them have no model at all in IEC 61850-7. An example of the first kind is fault recording as provided by most modern protective relays, which in IEC 61850-7-4 is defined having in mind traditional stand-alone fault recording devices, with a LN modeling each recording channel, either analog (RADR) or binary (RBDR). The closest LN which can model the fault recording features of modern multi-function relays is the generic RDRE. On the other hand, the important Sequence-of-Events function, also provided by most modern multi-function relays, has no LN model.

To fill this gap some IED manufacturers have created their own specific LN to have the corresponding functions available by 61850 communication services. For instance, for the Protection Related function *Switch Onto Fault* ABB created its own LN, named RSOF (*protection-Related Switch Onto Fault*).

Since a goal for the developed standard SAS solution is compatibility with all certified manufacturers, the followed strategy was to create a few slightly different versions of the specifications for the same bays. For example, in Fig. 4 the *Switch-Onto-Fault* function is modeled

by a PTRC LN, which fits IEC 61850-7-4 and most IED, but another version can be done from this one by replacing it by LN RSOF.

The description of the Power Equipment (Fig. 3) and of the related Automation functions (Fig. 4) are combined to provide a full specification for the Bay in Fig. 5. In present HV/MV Distribution Substations the power equipment itself is not smart, that meaning that it doesn't communicate through IEC 61850 communication services; instead, it provides wired Input and Outputs to the IED. However, these IED can themselves communicate, and so they become the real communication interfaces to that equipment. This way, the links between the LN describing the power equipment and the SAS functions in the SSD are intended primarily for documentation purposes.
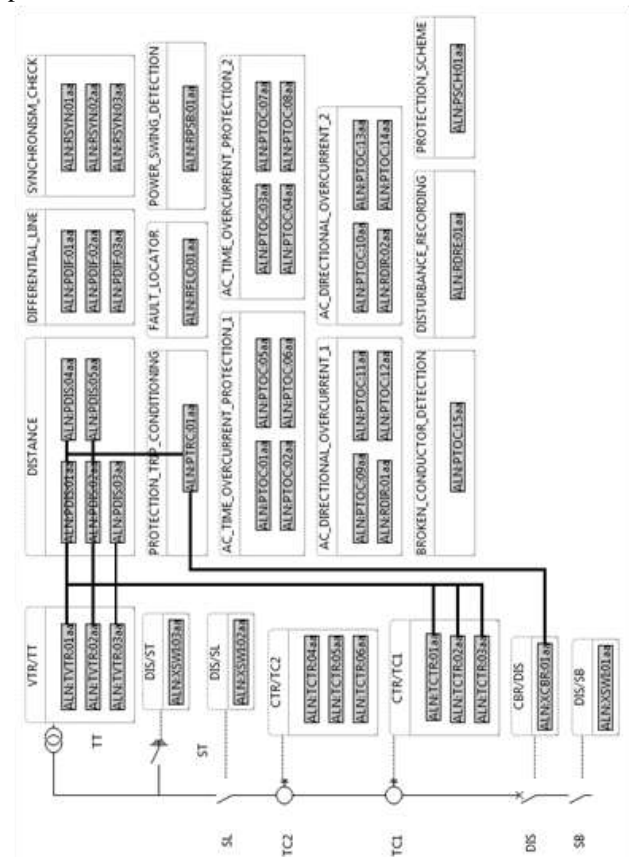

Figure.5: Complete System Specification for a HV incoming Bay

The same process is applied for all the other bays considered in the standard HV/MV Distribution Substation. When all bars and bays, with all the equipment and LN related to their functionality and to their SAS functions, are included, the final SSD is accomplished and ready to include the communication subnet and all the "certified" IED within. Therefore a complete SSD is generated for the Standard Substation.

MAPPING THE SPECIFIED POWER EQUIPAMENT AND RELATED AUTOMATION FUNCTIONS ONTO THE IED

After having built the SSD it is time to map the created LN to the LN available in the certified ICD provided by the manufacturers.

Integrating certified IED

IED are different from one manufacturer to another. However, for a standard Substation the set and features of the automation functions are standardized. On the other hand, the available space for mounting and wiring provisions for IED are also defined, so that the number and functionalities of the IED are also defined. Hence, we can talk about standard logical devices (groups of related LN) and even about standard virtual IED associated to each bay in such a Substation, although those virtual IED can be satisfied by a number of real IED, provided the required automation functions are a sub-set of the IED available functions.

Considering the differences between IED, this means that only a subset of IED from different manufacturers can fulfill the requirements of the Standard Substation, but all those IED have the same LN required by the standard Substation, even if they are only a subset of their capabilities. The IED fulfilling these requirements as well as electromagnetic compatibility and other hardware requirements can be considered certified.

The integration of the IED starts with the importation of the certified ICD to the Substation Configuration Tool and the construction of the communication subnet. This subnet is composed by all the IED used in the different bays, each one with an unique Internet Protocol (IP) address to provide an univocal identification within the Substation. After that the IED are linked to the respective bays according with their functionalities.

Although the assigning of IP to the IED is usually required to identify instantiated IED in instantiated Substations, which is a step already belonging to a particular Substation Configuration process in IEC 61850, since we are working on a Standard Substation with a maximum number of bays, we can consider it as a template for real Substations.
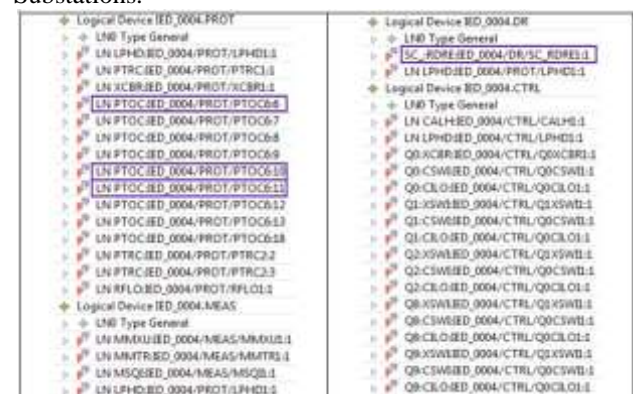

Figure.6: LN of IED SIEMENS SIPROTEC 7SJ645

Figs. 6 and 7 show the LN structure of a SIEMENS SI-

PROTEC 7SJ645 and of a EFACEC TPU S420 IED. The rectangles illustrate which IED's LN have been mapped to the LN defined respectively in the MV feeder and in the Transformer MV side bays of the SSD. As can be seen some of the LN of the IED are of the XSWI and XCBR classes. They intend to be the communication interfaces between switches and breakers and the SAS system.
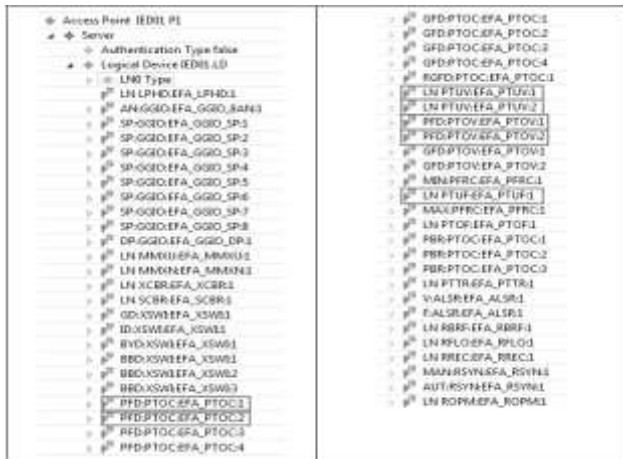

Figure.7: LN of the IED EFACEC TPU S420

Building a SCD

A usual approach to the engineering process is to have a library of ICD from IED fulfilling the Substation specifications and to configure them only after a particular manufacturer is chosen for a particular Substation bay. A set of SSD have to exist to deal with the different manufacturers. However, in Standard Substations it is quite common to prefer particular manufacturers for specific bay types (for instance, specific IED manufacturers for transformers MV side).

This supports the existence of a SCD with typical IED for the maximum number of bays, which in turn supports the instantiation of any particular SAS by only removing the unused bays. On the other hand, the number of different IED from different vendors which can perform EDP DISTRIBUIÇÃO requirements and specifications is not large.

Fig. 8 illustrates the mapping done with the Substation Configuration Tool from the HV incoming line bay Specification to two different IED, each one with different functions to perform according to EDP DISTRIBUIÇÃO HV/MV Distribution Substation standard project. After all the IED and substation's functions LN have been linked in the final SCD, this file is ready to be exported to the IED's Configuration Tools of the manufacturers involved in the project.
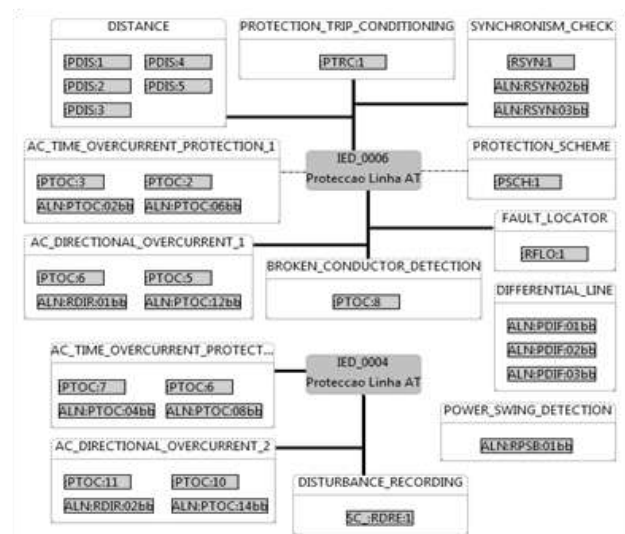

Figure.8: Mapping IED's LN to the HV incoming line bay defined control and protection LN

CONCLUSIONS

This paper shows how to build a standard HV/MV Distribution Substation Automation System using a top-down approach with the objects, processes and tools provided by IEC 61850. The goal is to minimize the engineering process of the SAS of new Substations by reusing a base project.

The proposed 61850 engineering process is based on two steps. The first step is the description of the standard substation specification by means of LN, and the second one is the integration of the different IED and their LN's structures, by means of certified manufacturers' ICD, plus the respective mapping to the SAS LN. The two steps correspond respectively to build the SSD and the SCD in the IEC 61850 engineering process. Creating a SSD for a standard design with a maximum number of bays and from there building a few SCD with the most typical IED from certified manufacturers (those which fulfil the utility SAS specifications as well as its mounting and wiring requirements), any new real (instantiated) Substation Configuration can be achieved by removing the unused bays and related IED. This approach can be used in other types of projects in which IEC 61850 is being used, thus dramatically reducing the development cost of their engineering process.

REFERENCES

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[4] IEC, 2010, *61850-7-4: Compatible logical node classes and data classes,* ed.2.0.