Efficient Secondary System Configuration Process Utilizing Centralized Substation Functions

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1. Introduction

Smart grid initiatives around the world show how much the control and protection of distribution networks is expected to change within the next few years. As the passive network with unidirectional power flow evolves into an active network with a variety of different active resources, the requirements for the primary distribution substations will also change, requiring the utilities to take action. Utilities are reluctant to undertake continuous and costly upgrades of the whole protection system, but there is still a clear need for adapting to new requirements. The need to increase the level of automation in the distribution system has been clearly noticed both on the vendor side [Hec09] and on the utility side [Gor07].

Continuous updates are expensive, not only because of new installations and new equipment, but also because of the necessary manual engineering and commissioning work. Modern protection and control IEDs are complex devices with extensive functionality requiring configuration work by skilled personnel before they can be taken into use. In addition to the configuring of various aspects of the IEDs themselves, the devices need to be integrated into the existing network control systems.

This challenge has also been addressed in the IEC 61850 standard, as the second edition of IEC 61850-6 was published recently [IEC09]. Clarifications and additions in IEC 61850-6 have an impact on the engineering process. The usage of SCL is now more explicit and in addition the roles of different engineering tools are now more accurately defined [Bru10]. The target of the new edition is to also harmonize the engineering process of IEDs from different vendors, so that upgrades and new installations would be feasible also in multi-vendor environments.

This paper shows how edition 2 of IEC 61850-6 and centralized substation level functionality can enhance the configuration process. It shows how both of these new elements support each other in the target for adding modularity to the secondary system of a substation and for defining clearer interfaces. In the presented concept configuration tasks related to bay level IEDs will be simplified due to a reduced complexity of the IED configuration tools. Advanced functionality requiring extensive configuration work can be allocated to the station computer, where updating causes less disturbance on the main protection and on the system level configuration. When the complexity of bay level devices can be reduced, also the number of IED variants requiring special engineering attention can be diminished. In the long run also the engineering processes of IEDs from different vendors may become more similar, which also facilitates the usage of the IEC 61850 standard. At the moment the standard is the dominating element in device communication and system modeling, but this progress has not yet greatly reflected engineering tools [Pau09].

2. IEC 61850-6 Edition 2

The recently published edition 2 of IEC 61850-6 also impacts the engineering process. The usage of SCL is now more explicit and, in addition, the roles of different engineering tools are now more accurately defined. Although the “real tool” can play many different roles, the target of the clarification is clear. The division between vendor and/or IED specific tasks and system level tasks must be clearer before interoperability can be guaranteed. It is not enough if IEDs from different vendors can communicate with each other via Goose messages, if it is not possible to configure these two IEDs with a similar engineering flow. Several different tools on the IED level can be accepted and is also often necessary, but the system level configuration must be possible to do with one single system level tool.

Different levels of engineering tools are described in the standard as the *IED Configurator* and the *System Configurator*. Different roles are visible in *Figure 1.*

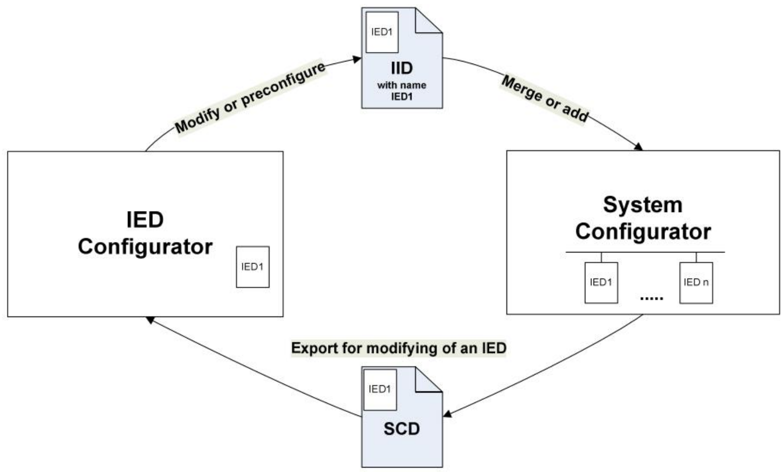

Figure 1. Two main levels – IED Configurator and System Configurator. Updates possible via IID files [IEC09].

All engineering data is transferred via SCL files, and the context of the SCL file is indicated in the extension of the file. SCD is the extension for system level configuration files and CID the extension for IED configuration files. For further clarification of the IED engineering process a new extension IID (Instantiated IED Description) was introduced, which is also meant for IED configuration and also presented in *Figure 1*. The difference between CID and IID is that IID does not have any Goose engineering information. IID is only IED specific and does not have any information about other equipment in the substation. IID can be edited entirely in the IED Configurator, whereas CID requires information from the System Configurator. *Figure 1* also illustrates how updating the configuration of an instantiated IED is now easier by using the IID file – any updates of the configuration do not affect the system level configuration. A model of the information flow in the whole engineering process is described in *Figure 2*.

As *Figure 2* illustrates, the target of the additions to IEC61850-6 is to make the configuration process more modular with more accurately defined interfaces. The IID file simplifies making modifications during the engineering process of one substation project, but also another new extension SED (System Exchange Description) was introduced for clarifying the interfaces towards other projects. This SED file is intended for transferring engineering rights between projects. If one project needs to update the data flow details of another project, the parts can be checked out from the project via SED files and later checked in again after modifications have been done.

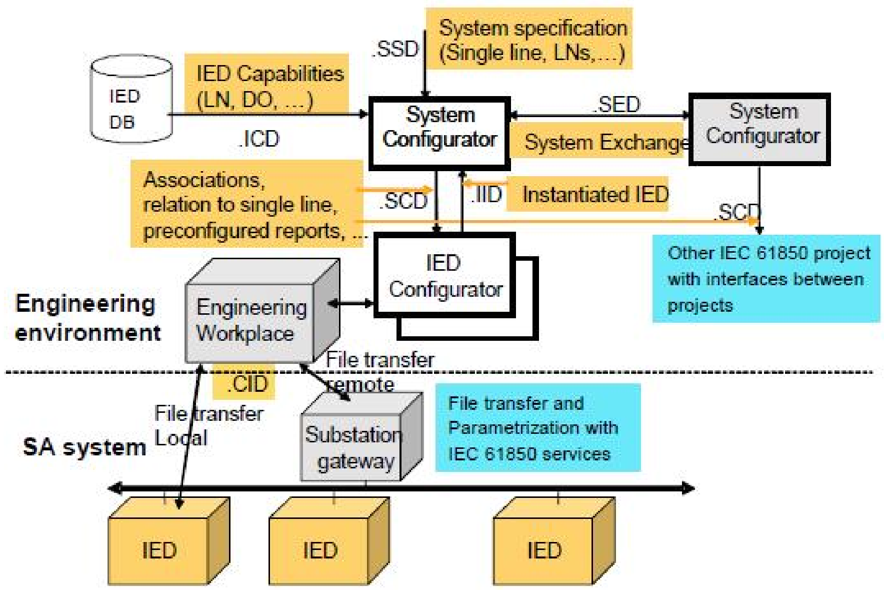

Figure 2. Reference model for the information flow in the configuration process [IEC09].

The updated standard encourages vendors to also harmonize their engineering process in the same manner that it has encouraged vendors to harmonize the communication. On the IED level vendor specific solutions are allowed and also necessary but looking down from the system level IEDs from each vendor must behave similarly. The introduction of IID files also allows more flexible modifications during the execution of the project. Within IID files the configuration details of an individual IED can be updated without affecting other parts of the substation, and e.g. reducing the need to "remap" Goose signals every time the IED configuration is changed. The intended modification process with IID files is described in *Figure 3.*

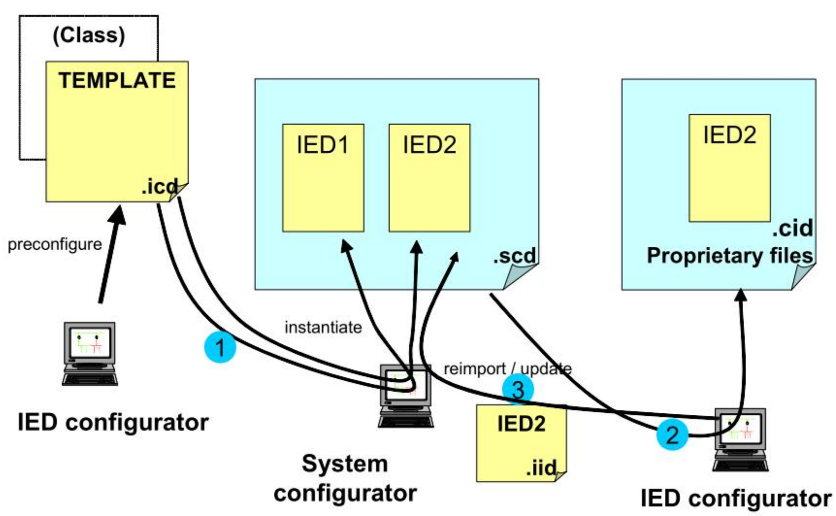

Figure 3. Modification process [IEC09].

3. Substation updates and engineering

Modern IEDs are complex devices and commissioning and updating them is normally handled by skilled personnel from the IED vendor or by a separate service provider. Utilities seldom have their own personnel for extensive engineering work, at least this is the case in Finland. The clear trend is towards increasing the utilization of external service providers. In many cases utilities have their own designers for determining suitable settings for the protection functions, but for other functional engineering, especially system level engineering of the substation their own know-how is limited.

The main challenge seen by utilities are testing and verification. Any new functionality must be tested on the system level, and this normally requires deep know-how of the devices in use. Test sequences also often mean interruptions in the supply of electricity or alternatively detailed and time consuming planning of backup connections. Therefore the target often is to avoid updates when the foreseen benefit is low, especially with updates affecting the system level engineering. Horizontal communication via Goose messages is often promoted by IED vendors as an easy way to add new functionality, since there is no need for additional copper wiring. The problem still often is the difficulty in verifying and documenting these additions. Also the functionality, which was not updated, needs to be tested. This all leads to postponing updates as late as possible, and also losing the benefit of new advanced functionality of modern IEDs. In Finland, typically only about 1% of the total asset value share of the distribution network is due to relaying and automation, although the effect of it has a profound implication on the reliability of the network [Val09]. Focusing on substation automation is a good chance to increase profit with relatively small investments, which is missed when the update process is too complex and time consuming.

Lack of generic system level engineering tools is often mentioned in technical reports [Cas09]. This is often not an issue for utilities, as this service is bought from other engineering companies. But the need for a generic tool to serve these engineering offices is apparent. Although IEC61850 has proven to be an excellent approach for increasing the interoperability between IEDs from different vendors, there is still a definite need for improvements. Still very often IEDs are selected from a single vendor, just for "reducing the possibility of trouble". In practice using N different vendors means N different tool chains, N different philosophies in the engineering process and perhaps even N different names for the same parameter.

When asking about the effort needed for configuring IEDs the answer is often "too much". E.g. graphical configuration tools are often seen as unnecessary. Engineering an IED should be as easy as ordering one – selecting which functions are needed, and assuming that logic connections are created automatically so that the functionality is in use – the only customization required would be the application and network specific setting values.

4. IEC 61850-6 Edition 2 Implications

How do the clarifications in IEC 61850-6 affect the engineering flow? What is the underlying main philosophy and how should vendors address this? This second edition is a natural continuation to other activities within IEC 61850 with the main target to increase interoperability – it should be possible to use two IEDs from different vendors in the same substation without extensive additional work. The actual functionality can and, in practice, also should be different, but using these different functions in the same substation should be possible with reasonable effort. Communication via Goose is already possible, but now the engineering should also be possible over a similar tool chain.

The updated standard implies that system level engineering including Goose configuration should be possible to do with an external 3rd party tool. This aspect does not only affect the engineering interface, but also the functionality implementation details. The functionality of IEDs should be self-contained in a manner, which supports multi-vendor solutions. If e.g. advanced functionality is distributed to all feeder IEDs, which need to be configured to communicate with each other via Goose (aggregated measurement values, intermediate calculations etc.), this does not strictly speaking follow the spirit of the standard. It forces the utility to order all IEDs from the same vendor because otherwise it would not be possible to use the functionality. The standard also implies that one piece of logical functionality should reside in one logical device, which in the standard also is to within one physical device.

With widely used and already standardized functions such as interlocking this of course is not an issue – the requirements for the horizontal communication data is as well standardized as is the Ethernet frame of the Goose message. Sending interlocking information between IEDs of different vendors is feasible and in use in many substations. The problem becomes more apparent regarding new advanced functionality, where e.g. intermediate calculation results are required to be shared between different bays, e.g. high impedance earth-fault detection utilizing measurements from all bays.

5. Possible architectures for the secondary system

The question is how to proceed with substation automation, so that both interoperability and fast utilization of new algorithms can be enabled. New technology enables gathering and processing much more measurement data than before, and the standard should not cause any problems for utilizing this technology. On the other hand the standard should prohibit the vendors from creating monolithic secondary systems, which can only be sold and maintained by a single vendor.

Various concept level proposals for the secondary system of a substation have been presented in order to address the conflicting requirements for low lifecycle costs and fast new technology utilization. The most traditional approach has been to increase the functionality of the bay level protection and control IEDs (Intelligent Electronic Devices). This approach has been sufficient, while CPU capacity has been steadily increasing and the price of new technology has remained at a reasonable level. The issue in this approach has been the extensive costs of upgrades. New features have also called for substantial changes in the substation's entire secondary system requiring long maintenance breaks or time consuming planning of backup connections. The principal view of this setup, along with the two other ones, is presented in *Figure 4*, where the mentioned setup is described as 'Decentralized'.

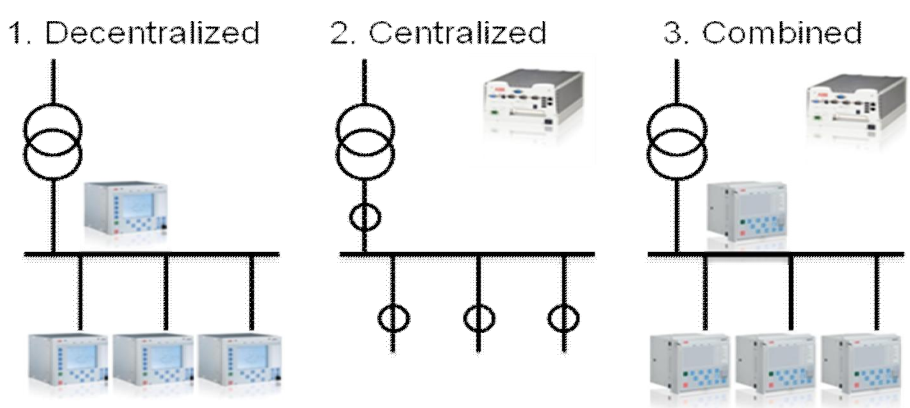

Figure 4. Possible Architectures.

Another approach has been to fully centralize the functionality in a distribution substation [Vol07] [Rie05] (Described in *Figure 4* as 'Centralized'). By moving all functionality to a centralized station computer the lifecycle of the bay level measurement devices has been greatly extended. Also the upgrade measures needed to implement new features have been simplified, because only the centralized station computer has required updating. This, however, creates a single point of failure in the substation. When the central station computer is out of operation, protection of the whole substation is lost. In practice, fully centralized solutions would always need a redundant protection system – either a redundant station computer or redundant bay level protection and control IEDs – which increase the overall costs of the substation secondary system. The same maintenance problem as with a fully decentralized solution also exists. When an upgrade is needed, the whole protection system needs to be upgraded. Maintenance breaks and extensive testing are required.

A third approach addresses the challenge by combining these two methods [Val09] (Described in *Figure 4* as 'Combined'). In this approach only a part of the bay level functionality is moved to a new substation level centralized station computer. The functionality is divided so that the most critical and important functionality would remain in the bay level devices assuring network safety in all situations [Val10]. This creates the back-bone of a network protection system with a long life-cycle. The functionality defined for the substation level would consist of value added applications and other "nice-to-have" features, for which a faster update cycle is necessary. The setup also has a natural inbuilt backup scheme, where bay level and station level devices provide a redundant protection system. The measures to update the central unit are cheaper and safer, allowing smooth utilization of new functions. In earlier research papers this approach has been evaluated from the cost-efficiency and functionality point of view, but the approach has also clear benefits with regard to the engineering flow and IEC 61850-6 Edition 2. The setup is presented in *Figure 5* and described in more detail in [Val09].

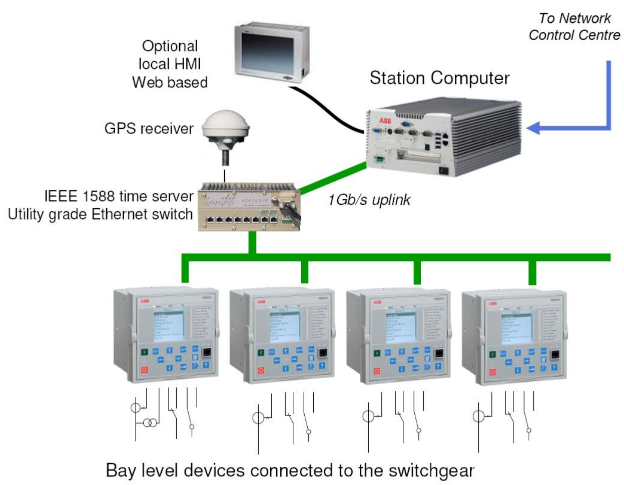

Figure 5. Overall setup of centralized protection and control system

6. Benefits of centralization

As shown above, implementing new advanced functionality in IEDs is a problematic task. It forces continuous updates to the whole protection system of the substation. Continuous updates are expensive, not only because of new installations and new equipment, but also because of the necessary manual engineering, commissioning and testing work. If the functionality utilizes measurements from more than one bay, an implementation on the IED level is only possible when all IEDs are from the same vendor.

From the standard point of view and also from the engineering point of view it is beneficial that system level engineering and functionality do not have unnecessary IED level vendor specific features. This also means that unnecessary Goose engineering on the substation level should be avoided. In addition to extra engineering work, testing and commissioning of such environments is a complex task, not to mention the documentation and maintenance issues. When the new functionality can be encapsulated within one logical device, the environment is more clearly structured. Testing, maintenance and documentation is easier to handle

New centralized station level protection devices and the IEC 61850-9-2 process bus provide a good frame for these new logical devices. When all measurements are available on the station level via IEC61850-9-2, new functionality is easily implemented by hooking to the process data via the process bus. The system level configuration can, at best, be entirely avoided. A review of such functionality suitable for station level implementation is presented in [Val10]. One good example of such a station function already on the market is the high impedance earth fault protection. Solutions exist, which require measurements (and separate wiring) to all feeder bays, in order to guarantee accurate detection of earth faults.

With this approach the complexity of bay level IEDs and also bay level IED engineering tools can be reduced, e.g. special graphical configuration tools could be skipped. Functionality is easier to divide into logical devices, which also is the target of the standard. These logical devices can then be acquired from different vendors and easily added to the substation as they all share the same interface – measurement data via IEC 61850-9-2 and other communication via Goose messages in IEC61850-8-1.

The engineering flow could be adjusted so that more of the functionality would be directed via the IID files introduced by IEC 61850-6 Edition 2. When a function resides in one IED/Computer/Logical device, it is easier to add it to the system and update it, and also easier to test and maintain it. Updates will not necessarily affect the system level configuration. Functionality requiring full system configuration changes should be avoided as it causes high costs during upgrade and commissioning.

In practice, this approach moves some of the implementation from Goose signals to the logical device internal logic. This implementation can be vendor specific, whereas Goose should not. The proposed architecture enables adding new advanced functionality as a single module to the station level – this module can be either new HW equipment or even a new SW module in a centralized SW platform, as visioned by the Swedish utility Vattenfall [Joh09].

7. Summary

Both centralized substation functionality and the second edition of IEC61850-6 support a more modular view of the secondary system. This modularity should be utilized, because the fast and smooth upgradeability it provides increases the cost-efficiency of the distribution network via optimal and fast deployment of new state-of-the-art functionality.

The second edition of IEC61850-6 defines the roles of different configuration tools in more detail. The target is that implementing a generic system level engineering tool would be feasible and that vendor specific solutions would be limited to the IED Configurator level. When new functionality is implemented within a dedicated logical device, instead of extensive Goose communication between all IEDs, the top level system configuration is simply more logically structured.

Expensive and time consuming commissioning and testing of the overall system often blocks updates and utilization of new advanced functionality. When the secondary system of a new substation is specified, careful attention must be paid to the upgradeability of the functionality. Nobody knows the full impact of the “Smart Grids impacts” emphasized and visioned for the future, but the most likely scenario is that the lifecycle of functionality in substations will get shorter. The architecture of the secondary system must be selected so that the lifecycle of the equipment is not forced to follow the lifecycle of the functionality and that possible updates can be done cost-efficiently.

The centralized concept presented in this paper maintains the overall life cycle costs of the secondary system of a substation on a reasonable level. When the new advanced functionality can be incorporated in the station computer software, the life cycle of bay level protection and control IEDs can be maintained long and the station computer upgrades can be made faster and cheaper, enabling smooth utilization of new advanced functionality.

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References

[Bru10] C. Brunner, 2010, IEC 61850 Engineering, PAC World, June 2010

[Cas09] J. Castellanos et al., Engineering Guidelines for IEC61850 Based Substation Automation Systems, Cigre Working Group B5.12, 2009

[Gor07] F. Gorgette, O. Devaux, J-L. Fraisse, 2007, Possible Roadmaps for New Requirements for French Distribution Control and Automation, CIRED 2007

[Hec09] J. Heckel, 2009, Smart Substation and Feeder Automation for a Smart Distribution Grid, CIRED 2009

[IEC09] IEC, Standard for electrical substation automation, IEC Standard 61850-6 Edition 2, The International Electrotechnical Commission, 2009

[Joh10] A. Johnsson, J.E. Söderström, P. Norberg, A. Fogelberg, 2010, Standard Platform for integrated soft protection and control, ISGT 2010

[Nib10] N. Nibbio, M. Genier, C. Brunner, E. Cottens, D. Muller, J. Reuters, 2010, Engineering Approach for the End User in IEC 61850 Applications, Cigre 2010

[Pau09] R. Paulo, A. Carrapatoso, M. Lemos, R. Bernanrdo, J. Campos, 2009, Advanced Engineering Tools for Next Generation Substation Automation Systems: The Added Value of IEC61850 and the Inpact Project, CIRED 2009

[Rie05] M.J.M. van Riet, F.L. Baldinger, W.M. van Buijtenen, F.J.T. van Erp, F. Volberda, F. Provoost, 2005, Alternative approach for a total integrated secondary installation in MV substations covering all possible and required functions, CIRED 2005

[Val09] J. Valtari, P.Verho, A. Hakala-Ranta, J. Saarinen, 2009, Increasing Cost-Efficiency of Substation Automation Systems by Centralised Protection Functions, CIRED 2009

[Val10] J. Valtari, T. Hakola, P. Verho, 2010, Station Level Functionality in Future Smart Substations, Nordac 2010

[Vol07] F. Volberda, M. van Riet, A. Pikkert, 2007, The Power of Simplicity, CIRED 2007