# LEVERAGING INDUSTRY STANDARDS TO BUILD AN ARCHITECTURE FOR ASSET MANAGEMENT AND PREDICTIVE MAINTENANCE

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## ABSTRACT

*Digitalization is becoming an increasing part of the strategy of many DSOs as it has the potential to create new business opportunities as well as to minimize operation and maintenance costs. Vattenfall Eldistribution sees standard based integration as a cost-effective approach to enable successful smart grid use case implementations. It seems to offer in the long run low integration costs and more importantly a greater flexibility, going from supplier specific integrations to a more generic and vendor agnostic approach.*

*This paper presents the result of a DSO pilot installation taking inspiration from IEC TC57 reference architecture, with the goal to provide substation data from the sensors at the substation to central level data storage and application in order to enable asset health analytics.*

*The pilot has demonstrated that it is possible to provide central applications with information from primary substations in a standardised way. The pilot also shows that a service oriented architecture together with the IEC 61850 and IEC CIM standards is flexible, agile and allow for reuse of information integration flows which means reduced integration costs and probably increased security.*

*Following the successful pilot, the next step is to look at how to fully implement and verify the concept in a real substation and to secure production grade components where prototypes have been used.*

## INTRODUCTION

Digitalization is becoming an increasing part of the strategy of many Distribution System Operators (DSOs) as it has the potential to create new business opportunities as well as to minimize operation and maintenance costs. EDSO for Smarts Grids highlight in their *Vision for a 'Digital DSO'* [1] three domains in which digitalization will play a great role for the DSO of the future: network management and operation, mobility and field operation, and market facilitation. For a digitally oriented DSO however, it is vital that its central applications have access in a secure way to the right data and with sufficient quality, in order to fulfil the potential that digitalization offers.

An example of a use case where a data driven approach could provide consequent savings to a DSO is condition monitoring and predictive maintenance of utility assets such as power transformers and circuit breakers. Accurate and early failure detection could not only save extensive costs for the DSO but also improve the quality of the power to the customers as power outages could be avoided. For it to be efficient however, predictive maintenance requires among others real-time or near real-time asset related measurements.

Intelligent Electronic Devices (IEDs) and dedicated sensors all have the ability to generate some of the needed data. However the data unfortunately currently often remain unused and unshared outside of the substation or specific silos for various reasons, some technical (e.g. cyber security, system incompatibility), some and organizational (e.g. vendor lock-in, siloed applications and organizations).

Additionally, with an increasing number of use cases requiring access to information, there is a growing number of information flows needed not only between data sources and central level applications but also between these central level applications. Without an IT architecture that allows reuse of information flows, there are legitimate concerns that the opportunities that digitalization promises might be delayed and costly or even worse, not be achievable.

As a result, Vattenfall Eldistribution sees a standard based integration approach as a cost-effective approach that seems to offer in the long run low integration costs and more importantly a greater flexibility, going from supplier specific integrations to a more generic approach.

Vattenfall Eldistribution together with Vattenfall R&D decided to take inspiration from IEC TC57 reference architecture in order to provide substation data from the sensors at the substation to central level data storage and application in order to enable asset health analytics.

These concepts have been tested internally in a pilot and this paper intends to show some results, conclusions and insights that were gathered during this pilot demonstration.

## INDUSTRY STANDARDS

### IEC TC57 Reference Architecture

The IEC Technical Committee 57 (TC57) encompasses a series of standards that are central for the successful implementation of the Smart Grid and all its related use cases. One of the main purposes of IEC TC57 is to provide a reference architecture that shows how the various existing standards activities within the IEC TC57 relate to each other and how they individually and collectively contribute to the realization of the Smart Grid.

The proposed reference architecture [2] for power system information exchange describes all the existing object models, services and protocols within the scope of TC57 and also how they relate to each other. Moreover, the reference architecture proposes a strategy and recommendations on where harmonization between standards is needed and how to achieve a common model which facilitates information exchange over a variety of industry-standard transport infrastructures.

Three standards, IEC 61850, IEC 61968/61970 (CIM) are central in the reference architecture.

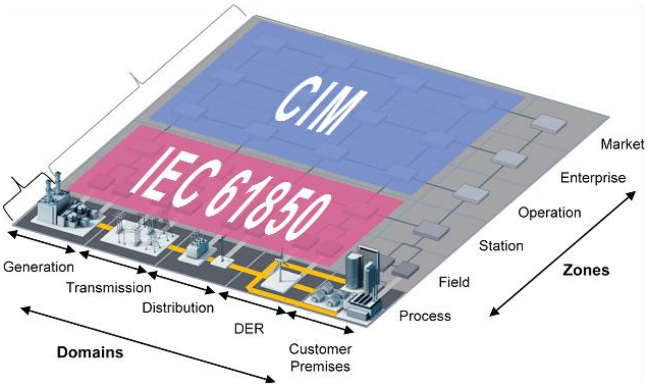


*Figure 1: IEC TC57 promotes the use of IEC 61850 standards for process and field implementation and CIM for implementations in higher zones.*

## IEC61850

IEC 61850 is a series of international standards defining engineering processes, information models and communication protocols for intelligent electronic devices at electrical substations, including but not limited to protection automation and control systems. IEC 61850 is already introduced and used as the technical standard for substation automation within the organization.

## IEC 61970

Standards to facilitate integration of applications within a control center, exchange of network power system models with other control centers, and interactions with external operations in distribution as well as other external sources/sinks of information needed for real-time operations. These standards include the generation and transmission parts of the Common Information Model (CIM), profiles for power system model exchange and other information exchanges, and eXtensible Markup Language (XML) file format standards for information exchange.

## IEC 61968

IEC 61968 is a series of standards under development that will define standards for information exchanges between electrical distribution systems. IEC 61968 is intended to support the inter-application integration of a utility enterprise that needs to collect data from different applications that are legacy or new and each has different interfaces and run-time environments. IEC 61968 defines interfaces for all the major elements of an interface architecture for Distribution Management Systems and is intended to be implemented with middleware services that broker messages among applications.

# THE PILOT

## Scope of the pilot

The scope of the pilot was to prove and demonstrate a modular and layered architecture utilizing a standards-based approach and more specifically to test the concepts of the TC57 reference architecture through a condition monitoring use case: to forward some of the data generated by IEDs at station level to one or several central applications through an enterprise service bus (as described in the IEC 61968-100) for further use. The pilot demonstration was realized in a lab environment, yet with real substation IEDs and the same communication network used by physical substations. Data is generated at substation level through remote I/Os and IEC 61850 compatible IEDs.

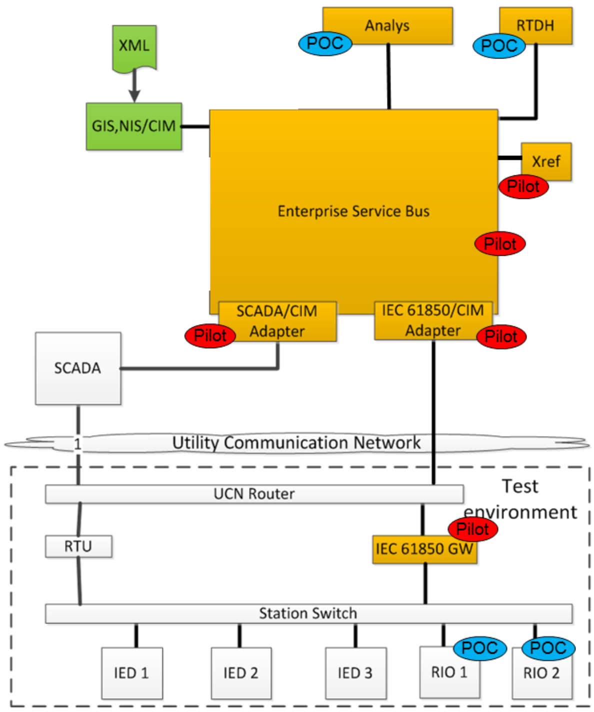


*Figure 2: A simplified schematics of the pilot infrastructure.*

Some parts of the installation have been defined as a pilot, where the installed environment will be implemented into real operation after successful results. For these parts, scalability is an important aspect to evaluate.
Other parts of the installation have been defined as proof of concept (POC), where the installation is a temporary set up to prove and demonstrate the feasibility of critical aspect of a solution.

## The pilot components

### IEDs and Remote I/Os (RIO)

The IEDs used in the pilot were standard circuit breaker IEDs that can be found deployed in some of our primary substations. For the pilot, RIOs were created to simulate real devices by combining physical sensors, Rasberry Pi (microcomputers) and open-source IEC 61850 server. They correspond to any 61850 compatible specific sensor that could be used to supervise specific attributes in this case of power transformers. The IEDs and RIOs were used in the pilot to generate measurement values and disturbance events.

### IEC 61850 Gateway

This substation gateway offers an alternative way for non-critical (in the sense of not being critical information for SCADA to operate the network) data to flow from the substation to central level, this way saving critical bandwidth to the RTU for critical flows of information only. The substation gateway provides a subset of a mirroring gateway according to the IEC TR 61850-90-2 (part specific for communication between substations and control centres). The gateway consists of: IEC 61850/MMS client side (towards the substation) and IEC 61850/MMS server side (towards central level). The substation gateway communicates (using IEC61850) measurement values to an adaptor on the Enterprise Service Bus (ESB). The role of the gateway in the pilot is to gather measurement values and disturbance events from the substation IEDs and RIOs and forward these through ESB services to central applications.

### ESB platform

An ESB was used as the integration layer as recommended by the IEC 61968-100. The ESB platform serves as a service oriented architecture (SOA) platform for to handle communication and integration between system at central level. An ESB does not implement a service-oriented architecture (SOA) but provides the features with which one may be implemented. For the purpose of the pilot, an ESB platform was chosen with ease of scalability (both technical and economical) in mind.

### ESB Services & Adaptor Services

The ESB services and adaptor services handle integrations amongst solution components and are the means by which a service oriented architecture is achieved for this pilot. Two types of services were used in the pilot: canonical services, based on CIM, that are generic and reusable, and adaptor services the translate legacy system messages into CIM compliant messages.

Some standard services are already defined in some parts of the IEC 61968 or IEC 61970. For example, the IEC 61968-4 defines interfaces for records and asset management and contains some messages for asset analytics or asset measurements. However none of these messages were fully implementable as-is in the pilot. Instead, new services were designed with the recommendation of IEC 61968-100 in mind. In the pilot, the payload of each canonical service was to be entirely based on information objects defined in the CIM.

The IEC 61850/CIM adaptor service was designed following the guidelines from [3] which provides an attempt at harmonizing the IEC 61850 and the CIM standards. Of interest for this pilot was the part regarding the reconciliation between the IEC 61970 measurement information model and the IEC 61850 logical node model.

### X-Ref DB

The cross reference database is in this pilot a simple SQL database used to store relationship between measurement IDs, asset IDs and equipment IDs (the role of the asset in the network) and is used by canonical services to retrieve the right information. In an EPRI report about standard based integration [4], the use of an asset information manager (could be seen as a full scale version of the cross reference database with all the needed features) with an information model based on CIM is promoted to achieve asset efficient asset health analytics across several systems.

### Analytics Application

In the pilot several analytics application were used to test the strength and flexibility (e.g. quick integration, vendor agnosticism) of this architecture. Since no real requirement were put on the actual analytics capabilities of the application, the focus was solely on the retrieval of the desired data using canonical services. The use of canonical services allows for legacy applications as well as in-house developed applications to retrieve the same data without any need of extra integration (the application only needed to call the right service).

## Engineering process during the pilot

The IEC 61850 also specifies the substation configuration description language (SCL) based on XML format for configuring and engineering the substation automation. The SCL defines the station single line diagram, function allocations, mandatory/optional and extensible data, services, communications, and configuration parameters. The objective of SCL is to have a common description of substation automation exchanged between different vendors.

For the pilot use case, asset health related data for circuit breaker were configured leveraging the substation automation configuration process and artifacts that the IEC 61850 standards define as well as standard tools already in place in the organization. The substation gateway was automatically configured using IEC 61850 SCL files, i.e. in the same way as other 61850 compliant IEDs in the substations are currently configured.

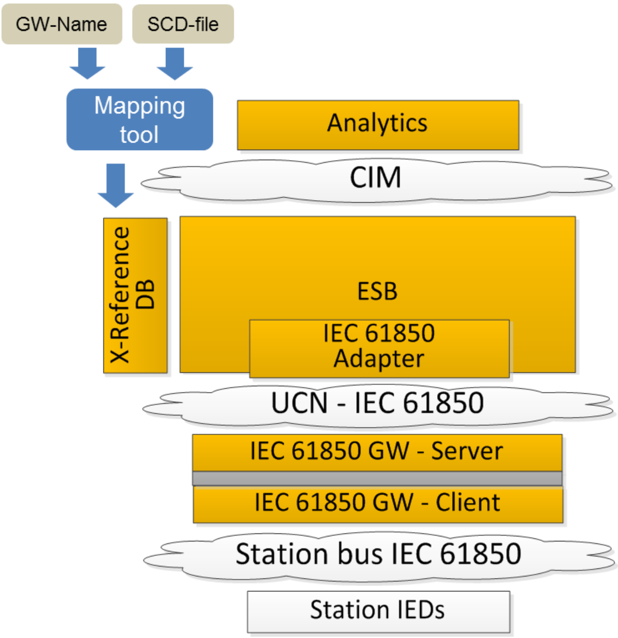


*Figure 3: An overview of the IEC 61850 information flow: IED – Gateway – ESB – Analytics application. The SCD file is used for configuration of the relation database.*

Moreover, the substation configuration description (SCD) file contains the needed information relating single line diagram instances to measurement data instances. These associations are necessary to be captured and passed through as the central applications need to know which asset health data relates to which asset. The XML hierarchy of the SCD file allows for automatic parsing of these associations. A parser was therefore developed during the pilot and its outcome used in order to populate the cross reference database. This way, a canonical service can relate the measurement IDs and associated data originating from the gateway to the correct Asset IDs.

## RESULTS AND INSIGHTS

The pilot demonstrated that it is possible to provide data consumers (applications or analytic solutions) with measurement value and event information from primary stations in a standardized manner. The pilot also shows that implementing canonical and application agnostic services enables the reuse of services and information flows: for example, although in the pilot measurement values could either come directly from the station gateway or via SCADA, the central applications were only exposed to one single information flow.

The reuse of services and the ability to develop applications independently and in parallel should provide Vattenfall with opportunities to increase business agility and the capacity to respond quicker to all the challenges and opportunities that the Smart Grid will and is already bringing to a DSO like Vattenfall.

Moreover, the pilot shows that the architecture greatly improves robustness in the solution by isolating the system components against changes in other components, as opposed to the traditional hardwired point-to-point integrations. Fewer flows and components to monitor and administer should furthermore lead to improved cyber security.

Finally, we believe that what has been developed during this pilot should be scalable, both in terms in terms of number of substation and number of data points but also that the architecture supports many more digitalization use cases

We would also like to highlight some of the deviations from the standards that were observed during this pilot:

The pilot made use of a REST API towards the real time data historian (RTDH in fig. 2), although there was no mention of REST in the 61968-100 standard. One could however expect, given the increasing popularity and use of RESTful services in most industries, that the standard will soon follow and that the mention will be added in a further edition on the standard.

The gateway used in the pilot was a prototype base on a technical report (IEC TR 61850-90-2) which is not yet a standard. This might explain why there doesn't seem yet to be a complete and robust 61850-90-2 compliant product on offer in the market. Another alternative considered for the pilot gateway was the use of IEC 61850/MMS towards the substation and the use of web services (either RESTful+ JSON or SOAP) to communicate northbound instead of the IEC 61850/MMS used in the pilot. SOA has indeed a robust and well developed architecture for distributed computing, and this should be leveraged. There however did not seem to be any products available on the market. This alternative will be explored in a coming pilot.

EPRI's Technical report [3] provides some guidelines for developing a 61850/CIM adapter service, but there are many mapping rules that need to be implemented in a solution to provide the full capability. Further to that, some IEC 61850 vendors have custom enhancements that require flexibility in configuring the adapter service, meaning that it might be hard to have a standard configuration of the adapter service at this stage. The creation of the working group 19 in the TC57 (Interoperability within TC 57 in the long term) is a step in the right direction however, where harmonization work between IEC 61850 and CIM has been undertaken.

## CONCLUSIONS

The pilot has demonstrated that it is possible to provide central applications with information from our primary substations in a standardized way. The pilot also shows that a service oriented architecture together with the IEC 61850 and IEC CIM standards allow for reuse of integration flows which means reduced costs, reduced development time and probably increased security as this means fewer flows to administrate and supervise. This loosely coupled architecture is flexible and scalable which will make DSO IT systems more agile for the coming changes in the Smart Grid business environment.

Although the pilot was made for a primary substation, the widespread use of the IEC 61850 standards series make the results of this pilot not only applicable for primary substations, but potentially also secondary substations and microgrid.

Following the successful pilot, the next step is to look at how to fully implement and verify the concepts in a real substation and to secure production grade components where prototypes have been used as well as test the architecture through other smart grid use cases.

## REFERENCES

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[3] EPRI, 2010, “Harmonizing the International Electrotechnical Commission common information model (CIM) and 61850”

[4] EPRI, 2014, “Standard based integration framework – Common information framework for asset health data exchange”