CIM-BASED SYSTEMS INTEGRATION PROJECT AT ELEKTRO CELJE DSO

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ABSTRACT

This paper gives an insight into the CIM based integration pilot project at the DSO Elektro Celje. This project was done as part of the bilateral cooperation project between the Slovenian TSO – ELES covering a consortium of partners and the Japanese agency NEDO with its' authorized contractor Hitachi, Ltd. The main goal of the project was to utilize IT integration standards based on the IEC CIM (Common Information Model – family of standards IEC61970, IEC61968 and IEC62325). The main aim was to integrate DSO's existing OT/IT systems (Geographic Information System – GIS and Metering Data Management System – MDMS) and newly introduced Distribution Management System (DMS). Within the project we have implemented multiple use cases in order to demonstrate the effectiveness of such an approach. In this paper we state what the goals were, as well as some implementation details about the project and eventually discuss the lessons that were learned during the project.

INTRODUCTION

The key enabler for the digitalization of DSO business environment is the combined use of state-of-the-art technologies and solutions, which requires efficient information exchange among various intelligent devices and information systems within the enterprise, as well as the exchange of data between companies acting in the energy market. However, the IT systems supporting distribution power system operation and control, metering, planning, maintenance, asset management and other processes, suffer from insufficient level of integration and interoperability. This is especially true for the information level of the integration stack, where a common semantic (i.e. IEC Common Information Model – CIM [1]) should be applied in the scope of an appropriate integration platform.

Appropriate methodologies and standards are well defined in the Smart Grids Reference Architecture [2] and related work done by CEN-CENELEC-ETSI Smart Grid Coordination Group, but despite the availability of this European Smart Grid standardization framework, there is a lack of best practices and experiences how to approach such integrations and how to leverage these standards for systems integration in the distribution companies.

In the scope of the Slovenian National Smart Grid project (also called the NEDO project [3]) the CIM based systems integration has also been addressed. Within the framework of the Nedo project, advanced smart grid functionalities have been established to provide for better coordination between stakeholders in the power system and its more efficient operation. Slovenian TSO Eles is managing and coordinating the project from the Slovenian side, while activities are carried out on the infrastructure of all owners of the power grid (besides TSO Eles also two DSOs) in Slovenia and two municipal communities.

One part of the Nedo project was addressing CIM integration of Elektro Celje DSO's OT/IT systems (GIS, DMS, MDMS, CIM repository). The integration was designed in accordance with the European Smart Grid Reference Architecture. The following use cases were implemented and tested at this DSO:

- Distribution network model (MV, LV) exchange from GIS to CIM model repository and to DMS
- Network operational state exchange from DMS to GIS
- Metering data exchange from MDMS to the DMS
- DSO – TSO data exchange: metering data of RES production (needed by RES forecast application at TSO).

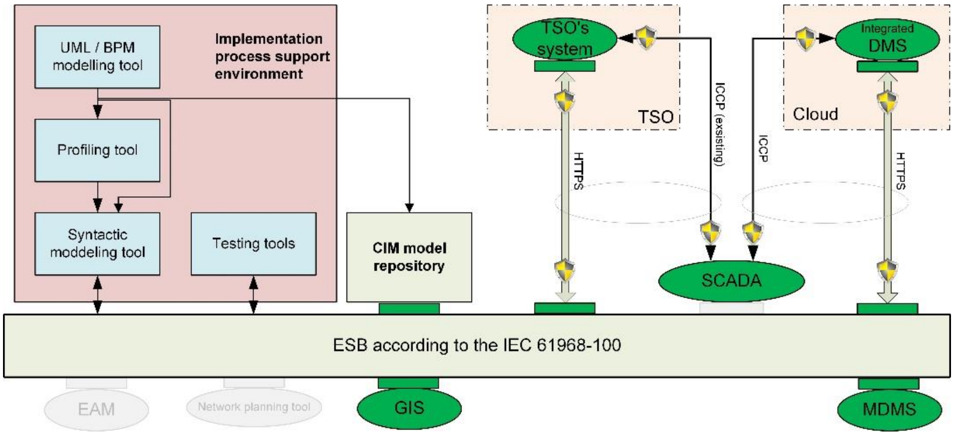

Figure 1: System architecture of the Elektro Celje CIM-based integration project

PROJECT GOALS

The main goals of the pilot project we wanted to achieve can be summarized as follows:

- To implement and test CIM based integration technologies.
- To make existing DSO IT systems (GIS, MDMS) CIM-aware.
- To develop a prototype of a reliable and proven platform which can serve for future DSO/TSO IT-systems CIM based integration.
- To research and develop advanced principles and semantic technologies of systems integration that would allow integration of existing and newly installed systems.
- To develop CIM UML profiles and related XSD/RDF schemes.
- To develop and test integration use cases, interfaces and mechanisms.

Throughout the implementation process we expected to - reach the following long-term goals within the IT organization of the DSO:

- To raise the data availability and quality level to a much higher level to be able to utilize advanced solutions such as Advanced Distribution Management System’s (DMS) functionalities.
- To reduce the integration complexity on the long term.
- To raise the data management infrastructure to a sustainable level so it could be implemented, tested and adopted by the DSOs as a long-term solution.
- To gain an integration platform which can serve as a cornerstone of such a sustainable infrastructure and allows for efficient data exchange between DSO’s systems, such as DMS, GIS, MDMS, Network planning apps, etc.
- To allow for vendor independent solutions due to usage of open standards.

IMPLEMENTATION

System architecture

Figure 1 show the system architecture of the integration platform. The platform is open-source and modular, which means that beside the core functionalities additional modules can be added with the least possible disruption to the system operations. To meet the requirements of the project we added, developed or configured several modules, bundles and interfaces.

The basic components of the integration platform are:

- Integration bus
- CIM repository
- Interfaces to integrated systems
- Implementation process support environment

Integration bus

The CIM integration bus is a component that in our case implements the ESB (Enterprise Service Bus) concept. It provides various services with the main objective of exchanging messages between integrated IT/OT systems (including CIM repository) according to IEC 61068-100 standard by implementing the following integration patterns [4]:

- synchronous request / reply
- asynchronous request / reply
- publish / subscribe

Message exchange and data flow are based on a concept of verbs and nouns that are defined together with a common envelope (CME - Common Message Envelope) in the IEC 61968-100 standard [4]. Verb defines operation type (e.g. Get, Create, Delete, Change, Cancel, Close, Execute.) whereas noun defines information type and is usually associated with the implemented use-case or profile. The combination of a verb and a noun, according to IEC 61968-

100 define a specific operation, which will be executed on all the relevant information systems (with respect to the integration pattern, subscribers and other criteria) based on message content.

Integration bus is also implemented with web service interfaces (SOAP, REST).

An ESB should provide a flexible, scalable and well-distributed infrastructure in which we can incorporate, implement and monitor any type of service in an agile and efficient way.

The main reasons to use an ESB were to differentiate data processing from data storage, to lessen the connections and to build monitoring tools on top of it. For the ESB we chose the Apache ServiceMix platform, which we customized to the needs of the project.

The custom Apache ServiceMix includes the following Apache features (group of bundles, configurations and dependency) that need to be installed for the system to meet the project scope:

- Apache Karaf: the runtime environment container
- Apache Camel: the framework to enable integration patterns (adapter, gateway, filter, aggregator, router, etc.)
- Apache CXF: a framework to build services in different formats (SOAP, XML/HTTP, RESTful HTTP) and work over a variety of transports (HTTP, JMS or JBI)
- Apache ActiveMQ: messaging broker and queue manager using JMS
- Hawtio: management console with web GUI

Apache httpd server

To deploy a single port endpoint for all the services that connect to the Apache ServiceMix ESB we installed the Apache httpd server. We configured the server to forward all the services endpoint received on the port 80 to the appropriate ports exposed on the ESB.

Apache ActiveMQ

The Apache ActiveMQ was implemented as the message broker; it was implemented inside Apache ServiceMix as a collection of features. It provides message persistency and dispatching to multiple subscribers. The reason for implementing a message broker in the platform was to be able to send and receive messages using the publish/subscribe mechanism, connect message consumers and message producers to read and write messages to and from topics.

ActiveMQ uses the JMS as a transport mechanism. The message broker is implemented according to the IEC61968-100 standard.

Message Proxy

This is a bundle we developed to enable messages to go through the Apache ServiceMix ESB, by using Apache CXF, and to be collected and stored and to provide a centralised point for security.

Figure 2 shows the implementation of the integration platform.

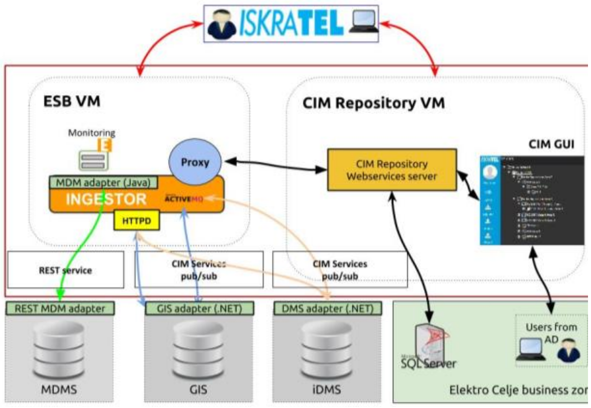

Figure 2: Implementation of the integration platform

For the production system all software was deployed on two VMware virtual machines, configured as shown in table 1.

hostname	ESB
vCPU	8 vCPU
vRAM	24 GB
vdisk	500 GB
OS	Microsoft Windows Server 2016 Datacenter Version 10.0.14393 Build 14393
hostname	CIM-REPOSITORY
vCPU	4 vCPU
vRAM	16 GB
vdisk	170 GB
OS	Microsoft Windows Server 2016 Datacenter Version 10.0.14393 Build 14393

Table 1: Configuration of virtual machines

CIM repository

CIM repository build a digital representation of the network, including physical network objects, network topology with geographical locations, and object registry with unique object identifiers. The main services that CIM repository offers are: network model exchange and objects registration.

The primary role of CIM repository is to maintain a master repository of network topology model data that is shared by different consumers/clients. When more than one information system acts as a creator of network model's objects, we need a repository that stores all the needed data to avoid duplication, provide uniqueness, sets an owner to every piece of information and dispatches the changes to interested systems. It acts as an aggregator and single source of truth to all the integrated systems.

Data stored in CIM repository is in our case in RDF XML format, recognized as flexible schema-less data model. Using a triple store database architecture, CIM repository enables to store network model data in native format. This enables high flexibility and performance in large payloads of model exchange. Other key advantages are:

- Enabling direct conversion from RDF CIM model format into chosen database format.
- Don't need to make a complex data schema.
- Don't need to link tables, you can do one too many relationships directly.
- Can add a new attribute (predicates on the fly), that are instantly available for querying due to automatic indexing.
- Simple management of CIM profiles.

Three services are deployed to govern the function of the CIM repository:

- *ORS- Object registry service* - is used to register an object in CIM repository. The service, upon successful object creation, adds a unique mRID to the object. All notified systems can add a local name to that mRID. The service handles the namespaces, system's local IDs and system's local names and sets the creating authority (object owner).
- *IS- Integration service* - handles the modification of object and parameters as described in the IEC 61968-100 standard. The operations on the objects assume the CRUD (create, read, update and delete) principle to manipulate the objects in the database.
- *LS- Loading service* - handles bulk data import/exports, backups and system restores. It uses high speed technologies to process large amounts of data at once.

The pilot project's CIM repository currectly includes around 27 thousand objects. Out of which there are 748 objects of type ACLineSegment, 193 objects of type Substation, 190 of type Power transformer, 23 Breakers, 174 Disconnectors, 171 Fuses and 186 LoadBreakSwitch objects.

We estimate that the complete Elektro Celje DSO system (MV and LV network) has a total number of around 500 thousand objects, so our current model contains just around 6% of them. The solution was designed in a way that can cover the complete system.

Interfaces to integrated systems

GIS interface

The DSO has provided a part of their electrical network for the pilot project which included the following subset of their network:

- One 110/20 kV substation
- 6 20 kV feeders with all the MV elements
- 190 MV/LV substations
- two LV networks

Electrical network topology of this equipment and equipment properties have been available in the DSOs' existing GIS system (ESRI ArcGIS & UT). In the project we have developed a configurable CIM adapter which transforms GIS objects and topology to CIM object and network model. The adapter can provide both full network export and transfers of changes from GIS to ESB and CIM repository. It also integrates information from other systems (e.g. network operational state from DMS) back into the GIS system for the sake of visualization which feeders are energized and which not.

MDMS interface

This is a Metering Data Management System, which stores metering data from smart meters (Advanced Metering Infrastructure – AMI) in a centralised database. The DSO is actually using two different systems from two separate meter manufacturers - IskraEmeco and Landis&Gyr. The CIM interface was done following the guidelines within IEC 61968-9 by utilizing a manufacturer-independent adaptor on top of both MDMS systems - we used the SmenDataBox solution which provides a REST webservice for the CIM MDMS interface.

DMS interface

The Integrated DMS system provided by Hitachi has been implemented in the cloud environment. This system was integrated with the CIM ESB in order to achieve the desired project functionality which was described in the introduction section of this article. It must also be said that these were not the only functionalities addressed by the system since the complete project also involved another DSO – Elektro Maribor which was based on a Microsoft technology oriented CIM platform. In that project Demand Response (DR) functionality was also deployed. The main advanced functionalities which the DMS provided into the project were: state estimations, fault location isolation and service restoration (FLISR), voltage control, etc., The system enables also the calculation of short term load forecasts (STLF) for the DSO. The distribution network model (MV, LV), which originates from the GIS, was imported from the CIM repository via DMS CIM interface in a fully automatic manner where the DMS was configured directly from the CIM model without the need for any manual interaction at the DMS side. The network topology after a successful import can be seen from figure 3 below. The figure shows the topology of the modelled network where different colours denote different MV feeders. The LV network was also modelled for two MV/LV transformer stations. The yellow circles denote their locations, but no detailed view of the LV network is given at this zoom level.

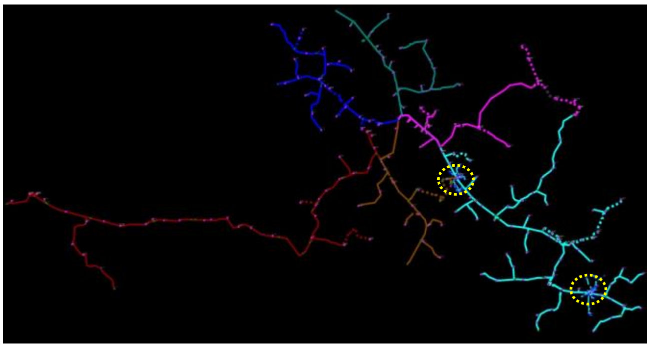

Figure 3: Pilot project's network topology as seen from the DMS system

Implementation process support environment

Before we could do any actual implementation, the data schemes had to be prepared in a meticulous and systematic way in order to define the data structure. For every particular use case it was therefore necessary to prepare a particular data profile for the data exchange. The data schemes were prepared in RDFS or XSD format and served for integration purposes in the scope of the CIM integration platform.

As the UML modelling tool, we have used both the Sparx Systems - Enterprise Architect and the CIMTool. Both these tools also provided the means to create CIM profiles. In Enterprise architect we used the CIM-EA toolbox for this purpose whereas the CIMTool provides profiling functionality inherently.

For testing purposes, we used the CIMTool for validating the network model instance against the RDFS schema. The Open Grid System - CIMphony Orchestra tool served the purpose of CIM RDF XML data visualisation and data inspection.

For the project we were using the canonical CIM model with the following versions:

- iec61970cim – version 17.07
- iec61968cim – version 12.10
- iec62325cim – version 03.02

In some cases, we had to extend the CIM model with new classes.

CONCLUSION

The CIM based integration platform has been successfully implemented. The pilot project's results have proven that the intended project goals have been achieved. In the near future the CIM-related IT integration projects within DSOs/DNOs will become more and more common due to the fact that related CIM standards have become mature after almost 20 years of development as well as the fact that much experience has been gained from the TSO related projects such as Common Grid Model Exchange Specification which is governed by the ENTSO-E [5].

The project results allow the DSO to achieve easy future scalability which will involve more IT/OT systems to be integrated and upscaling the size of the current integration levels.

The main lessons which we have learned can be summarized below:

- The CIM based system integration, which brings standardized common semantics and service bus solutions, reduces integration complexity and avoids many 1:1 integrations, that can lead to the so called "spaghetti integration architecture" which is expensive and hard to maintain on the long term.
- It is especially suitable for exchanging structural data (network models) due to well defined semantics in the IEC CIM standards.
- Implementing a CIM requires that a distribution company first analyses how existing data will be mapped to the CIM. A careful analysis on how existing data and systems will be modified, wrapped, or replaced, should also be performed.
- Having a well-defined implementation process and resulting CIM profiles with a corresponding validation processes is of paramount importance.
- Performing a pilot project is a good start for CIM based integration projects.
- The CIM based integration should be supported by well-defined integration strategy and roadmap.
- Data quality problems should never be underestimated. Sustainable data governance should be set up which involves setting up appropriate processes and adequate IT support. This in terms ensures a high level of data quality and consistency, notwithstanding that changes occur daily, in different departments and through various systems.

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