Semantic Interoperability for Operational Planning for the Electric Power Distribution System

A. ESPINOSA-REZA[1], H.R. AGUILAR-VALENZUELA[2], M. MOLINA-MARIN[1], M.L. TORRES-ESPINDOLA[1], T.M. CALLEROS-TORRES[1], E. GRANADOS-GOMEZ[1], R. GARCIA-MENDOZA[1], C.F. VILLATORO-HERNANDEZ[1]
[1] Instituto de Investigaciones Electricas, Reforma 113, Col. Palmira, Cuernavaca, Morelos
[2] Comision Federal de Electricidad, Lago Iseo 236, Col. Anahuac, Mexico, D.F.
MEXICO
aer@iie.org.mx and hector.aguilar05@cfe.gob.mx

Abstract: - This paper shows the Semantic Interoperability architecture based on the Common Information Model (CIM), IEC 61968, IEC 61970 and related standards for integrate a series of software tools focused on decision support for the operational planning for the Electric Power Distribution System, adopted standards and implemented software tools are discussed. The document shows some results and benefits towards implement enterprise architecture for Smart Grid in Mexico.

Key-Words: - Semantic Interoperability, Common Information Model (CIM), Smart Grid, Electric Power Distribution System (EPDS).

1 Introduction

Many references describe the Common Information Model (CIM), for example, "The Common Information Model (CIM) is an open standard for representing power system components." [3], as well as "CIM is an Information Model that applies the Object-Oriented paradigm of Software Engineering in order to represent the elements of the real world that are used for the infrastructure, management and operation of the electric systems of Transmission and Distribution, such as cables, lines, transformers, switches, protections, structures, poles, measurements, among others." [1].

The CIM is a generic, open and standard Model defined in a group of standards of the IEC, being the most important: IEC 61970-301, IEC 61968-11 and IEC 62325-301 [3], [1].

Many works related to CIM have been performed for many years, proof of concepts, prototypes, demonstrations, interoperability tests, systems integrations, standardization, extensions to integrate new utility fields, software tools for supporting the adoption process, and successful deployments. Currently, there are some documented case studies related to the present CIM implementation in utilities. The DTE Case Study report [2] introduce that in DTE Energy "Any single integration that used to take 3-4 weeks now can often be done in 3-4 days", also adds that "There is an upfront cost to implementing the CIM message for the first time and determining what part fits for that use case but the total cost of ownership is less because that initial effort is not repeated for every new interface or change".

Many documents show, in different levels, the CIM philosophy, and its adoption process [1], [3], [6], and the direct relation to the Enterprise Architecture is evident [5], [8], and its impact to Smart Grid strategies [4], [12].

In this sense, an implementation of a CIM-Based Semantic Interoperability Strategy in a utility must fulfill many requirements, including: international standardization for information modeling; efficient, secure and standard data interfaces for information exchange; a long term plan to integrate an Enterprise Architecture in order to align systems, business process and strategy objectives, among others.

2 Problem Formulation

The Valley of Mexico – Centre (DVMC by its Spanish acronym) at Comision Federal de Electricidad (CFE) is in charge of electric power supply to at least 2 millions of customers in Mexico City and metropolitan area of The State of Mexico, the most important and populated city in Mexico.

2.1 Operational Planning

The Electric Power Distribution System (EPDS) is dynamic, is changing continuously; the technical and business process for operational planning for the EPDS is very complex and commonly includes:

- Distribution Control Centers (with Human Operators 24x7).
- Measurement and communications systems.
- Devices for control, protection and automation.
- Software tools running almost 24x7:
  - SCADA: Supervisory Control and Data Acquisition.
  - ADA: Advanced Distribution Automation.
  - FDIR: Failure Detection, Isolation and Reestablishment.
  - VVC: Volt and VAR Control.
  - IAP: Intelligent Alarm Processing.
  - DMS: Distribution Management System.
  - DOMA: Distribution Operation Modeling and Analysis.
  - CA: Contingency Analysis.
  - OMS: Outage Management System.
  - TCS: Trouble Call System.
  - CIS: Customer Relationship System.
  - WFMS: Work Force Management System.
  - GIS: Geographical Information System (including electrical information).
  - DSM: Demand Side Management.
  - AMI: Advanced Metering Infrastructure.

Fig. 1. Typical view of a Distribution Control Center.

Fig. 2. Software tools for 24x7 monitoring the EPDS.

For the Smart Grid, the National Institute for Standards and Technology (NIST) developed the “Framework and Roadmap for Smart Grid Interoperability Standards” and describes in [4] the basic interactions for the Distribution Domain; it includes electrical and informational links (Fig. 3).

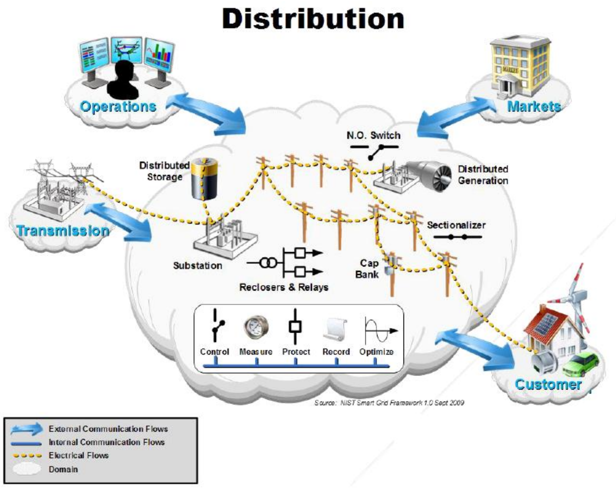

Fig. 3. Overview of the Distribution Domain [4].

All of those elements must interact in a confident way in order to work for the same goal: Electric Supply with high levels of reliability, quality, economics and considering the lowest impact to the environment. To do it, the processes required for operational planning includes human interactions, optimal decisions, historical analysis, electrical behavior evaluations, “what if…” scenarios, comply procedures and manuals, interactions between actors (humans and systems), among others, all running in time near to real time (1 second, 1 minute, 1 day, 1 week) because the dynamic of the EPDS invalidate all calculation results, e.g. if an event modify the network topology between the analysis and the execution of actions in the network.

In this sense, it is necessary a great strategy to reach real interoperability among systems.

2.2 Point-to-point integration

Many software systems are necessary to operate and manage business process related to the Electric Power System in all levels, control systems, transmission operations, distribution operations and management, stability control and data log, electric flow optimization, commercialization, data monitoring, transactions management, billing, customer relationships management, among many others; traditionally each software system whether from different software companies or home-made. Each component of this ecosystem of “solutions” use a proprietary data format and include valuable information for other system or business process in the value-chain of energy supply, for example, daily demand profile is necessary to dispatch the energy market in a deregulated power industry.

Exchanging data between legacy software systems is always problematic and traditionally a point-to-point strategy is applied.

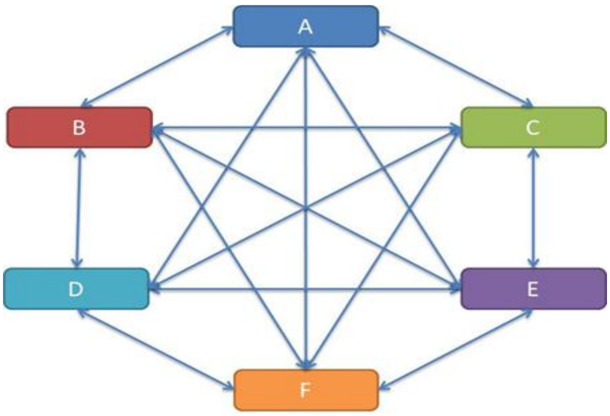

Fig. 4. Traditional point-to-point integration strategy.

2.3 Enterprise Application Integration

Enterprise Application Integration (EAI) replaces these dedicated links with a single communication link called a “message bus”. Using middleware services, this provides a mechanism for applications to communicate using a pre-defined message format and requires only a single interface to be written for each application. [3]

For applying the EAI in a utility, many standards and best practices must be adopted, for example generic services loosely-coupled are necessary in order to replace each specialized and highly-coupled interface, a well-defined data model must agree with the meaning of exchanged information, a service oriented architecture (SOA) using the associated technology as Web Services, XML, UML, etc. and an Enterprise Service Bus (ESB) in order to include an efficient, agile and robust data exchange technology in a standardized format.

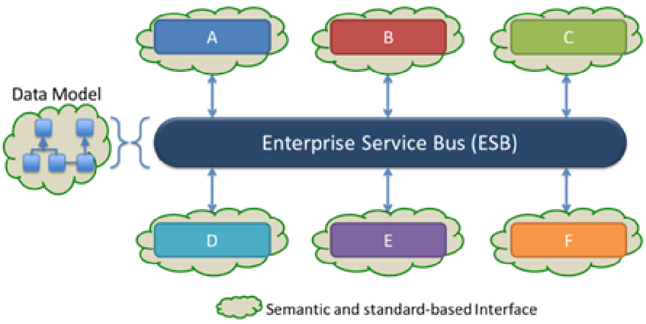

Fig. 5. Enterprise Application Integration strategy using semantic and standard-based interfaces.

In this new paradigm for systems integration, many challenges must be addressed:

- A common data model must agree and must explain the meaning and business process mapping for each exchanged data.
- Duplicity, inconsistency and incompatibility must be resolved [5].
- Avoid specialized and highly-coupled interfaces.
- Changes in one system and new systems integration must have minimal impact on other existing systems.
- Improve the situational awareness and governability about information exchange.
- Allow integrating complex event processing and advanced analytics functions.
- Integrate a secure architecture in order to improve cyber security.

3 Problem Solution

The architecture solution for implementing an Enterprise Application Integration strategy have many options, this section shows the specific architecture selected for the implementation of a CIM-Based Semantic Interoperability Strategy for Smart Grid at CFE in the Valley of Mexico–Centre.

The energy Distribution process at DVMC is managed by many operational systems, the most important are:

- SCADA at the Distribution Control Center.
- Distribution Management System (SIAD).
- Steady state monitoring, and energy quality supervision (SIMOCE).
- Licensing and manoeuvres management (GIL).
- Advance metering infrastructure for customer consumption monitoring (AMI/MDM).
- Geographical Information Systems (SIGED).
- On-Line Simulator for analysis and fast restoration in failure case (SimSED).
- Customer relationship management and services requesting (SICOM and SICOSS).
- Billing (SICOM).

The first implementation of a CIM-Based Semantic Interoperability Strategy for Smart Grid at CFE in DVMC includes the most important information exchanged between some of these main systems.

3.1 Semantic Interoperability

Interoperability refers to the capability of two or more networks, systems, devices, applications, or components to exchange and readily use information securely, effectively, and with little or no inconvenience to the user. [4].

For this paper, Semantic Interoperability refers to second category in the framework defined by the GridWise [8]. The semantic category focuses into what information is exchanged and its meaning. It establishes the understanding of the contained concepts in the data structures of exchanged messages, and integrates knowledge of the business related to the semantics or meaning in the work flow of a process. [1].

3.2 Implemented Architecture

The implemented architecture (Fig. 6) considers an integral solution for the Enterprise Application Integration at DVMC and includes many components, the most important are:

- Generic **Enterprise Service Bus** (ESB) in order to integrate a middleware to abstract the data layer and data sources, and supporting the SOA implementation.
- **CIM-based interfaces** or "CIM Wrappers" as is defined in [1]. Each integrated system by ESB, uses a CIM Wrapper.
- **Data Model Manager** in charge of managing the CIM Profiles governability and ensuring the unification capability of the many partial CIM Profiles.
- **Data Associations Manager** in charge of executing logic associations between legacies ID's of legacy systems.
- **Client application** for CIM Instance consumption. It calculates the Phase Unbalance in Distribution feeders and shows the profile behaviour in time. It includes a database simulating a "DataMart" for calculated values and to improve the user time response and experience in general.
- **OPC UA interfaces** to integrate real-time and historical data by SCADA and SIMOCE. The CIM Based interfaces include a data access layer implemented by means of OPen Connectivity Unified Architecture standard.

This architecture runs in a cluster integrated by 3 Physical servers considering 28 Cores and 48 GB of RAM (total).

Operational System for each server is MS-Windows 2012 Server 64 bits and the main database is MS-SQL Server Standard Edition.

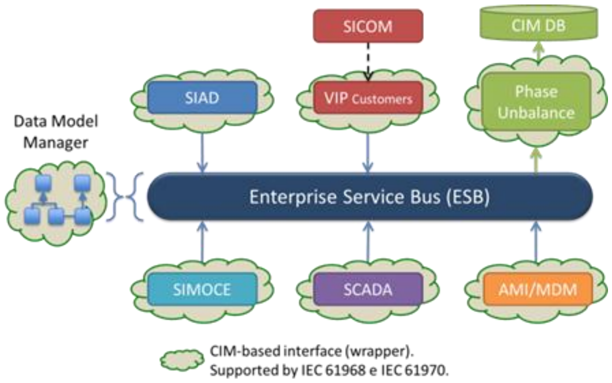

Fig. 6. The CIM-Based Semantic Interoperability Strategy implemented for Smart Grid at CFE in the Valley of Mexico – Centre.

4 Standards and Methodologies

Standardization was the main objective to reach in the DVMC – Semantic Interoperability strategy, some of the most important standards and methodologies are:

Data Model Standards:

- IEC 61970-301 which defines the CIM Base for Transmission Power Systems for use in Energy Management Systems (EMS).
- IEC 61968-11 which defines the CIM extensions for Distribution Power Systems.
- IEC 62325-301 that establishes the extensions for the Electric Market or CME (CIM for Market Extensions).
- IEC 61970-501 which defines a CIM RDF Schema.
- IEC 61970-552 which defines the CIM XML Model Exchange Format.

Interface Standards:

- IEC 61968-1 which defines the interface architecture and general recommendations.
- IEC 61968-9 which defines standard interfaces format (for meter reading and control).
- IEC 61968-100 that specifies interfaces implementation Profiles.
- IEC 62541 which defines the OPen Connectivity Unified Architecture (OPC UA) used in industry for integrating standard interfaces and communication protocols between control systems.

Best Practices:

- Extensible Markup Language (XML) that defines a set of rules for encoding documents in a format which is both human-readable and machine-readable. It is defined by the W3C.

- Resource Description Framework Schema (RDFS Schema) provides basic elements for ontologies description (knowledge representation). It specifies how to formally describe the elements in an XML document.
- XML Schema Definition (XSD) allows to formally describe the elements in an XML document. It is defined by the W3C.
- Web Services is a method of communication between two electronic devices over a network. It is defined by the W3C.
- Windows Communication Foundation (WCF) is a runtime and a set of APIs in the Microsoft .NET Framework for building connected, service-oriented applications.
- Java Message Service (JMS) is a messaging standard that allows application components based on the Java Enterprise Edition to create, send, receive, and read messages. It allows the communication between different components of a distributed application to be loosely coupled, reliable, and asynchronous.
- Service Oriented Architecture (SOA) is a design pattern providing application functionality as services to other applications. It is independent of any vendor, product or technology.
- Business Process Model Notation (BPMN) is a graphical representation for specifying business processes, which is developed by the Object Management Group (OMG).

Methodologies:

- IntelliGrid Methodology for Developing Requirements for Energy Systems [12].
- CIM Extensions method as in [3].
- Unified Modelling Language (UML) to describe CIM components about the electric power system.
- Open Unified Process for incremental development process.
- Business process management (BPM) for implementing a process optimization process.

5 Software Tools

Software tools were used in order to integrate all components, from modelling to automatic code generation.

- Enterprise Architect: CIM modelling, extensions and formal description of information components.
- CIMtool: used by CIM Profile generation and validation. The output could be a RDFS Schema, an OWL or an XSD file that includes the knowledge representation of the information to exchange.
- CIMer: a home-made software tool to create automatically source code from a CIM Profile.
- CIMit: a home-made software tool to create CIM Instances files from a specific data source using a CIM Profile.
- Data Model Manager: a home-made software tool including many basic functions to manage many partial CIM Profiles, for each integrated legacy system

In an Electric Utility, many Areas, Departments and Divisions conforms the organizational structure, if modelling it is necessary, then it is necessary define a unified strategy because CIM includes only two hierarchical Classes regarding electric structure from a geographical point of view: *GeographicalRegion* (A geographical region of a power system network model) and *SubGeographicalRegion* (A subset of a geographical region of a power system network model).

Data Model Manager includes functions to prevent inconsistencies among partial CIM Profiles, for example, many areas should model their organizational structure in the Unified CIM Profile in an organized and harmonized way.

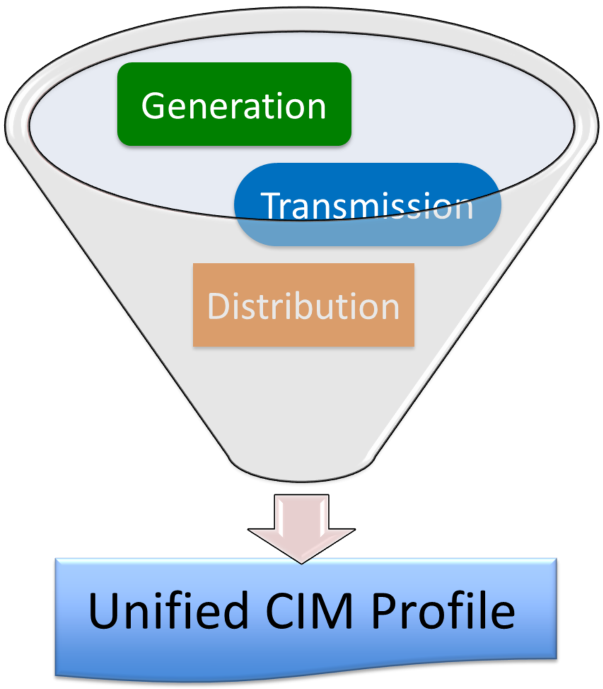

Fig. 7. Unified CIM Profile merging problem.

In this sense, all areas will try to use the same CIM Class to its highest hierarchical level.

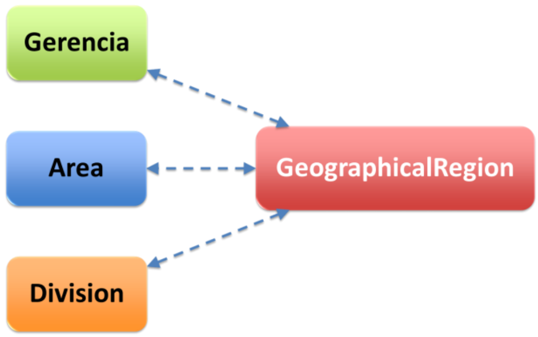

Fig. 8. Unified CIM Profile mapping problem.

Data Model Manager considers these problems and supports the unification ability for each partial CIM Profiles avoiding concepts overlap, errors in mapping and showing ambiguities.

6 Actual Benefits

When an Enterprise Application Integration strategy is implemented using real data, many new ideas are generated in order to integrate advanced functions; functions that previously were very complex due to many limitations of information availability and data consistency.

The first benefit of DVMC Semantic Interoperability strategy is the information availability and the ability to integrate many data sources from legacy systems using each a generic and unique interface. In this case, the developed Data Model Manager includes a Web Graphical User Interface (GUI) to explore the unified data model (CIM based) and CIM extensions, as well as, the ESB queues for each data source (legacy systems).

Fig. 9. The Web GUI for Data Model Manager includes a description of ESB queues for each data source integrated by CIM Wrappers.

The second benefit is related to ability to merge incompatible data. Using a BPM strategy, a business process was described in order to calculate Phase Unbalance from Distribution feeders and the process was automated supported by CIM Wrappers.

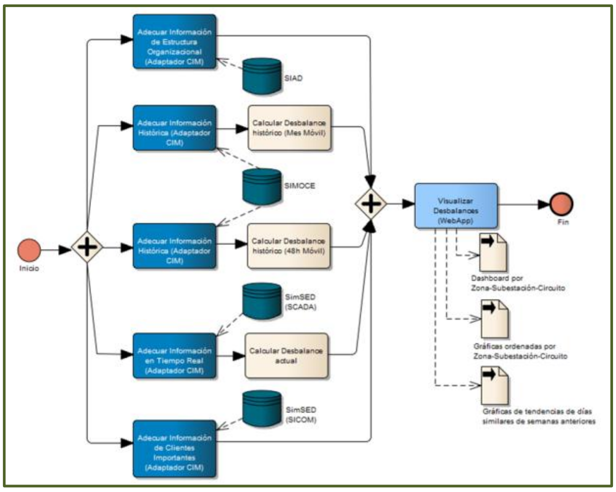

Fig. 10. The BPM diagram showing the process to calculate Phase Unbalance from Distribution feeders.

The application includes 3 time spans: Mobile Month (30 days before now), Mobile 48 Hours (2 days before now) and Real-Time (last acquired value). Mixed data sources includes SIAD (Enterprise organizational structure and electrical hierarchy), SIMOCE (Historical data) and SCADA (Real time data).

The business process for Phase Unbalance correction was completed considering many systems and external interaction, for example work orders for crew management, detailed analysis using on-line simulator, and results validations. Next figure shows a view of the full process.

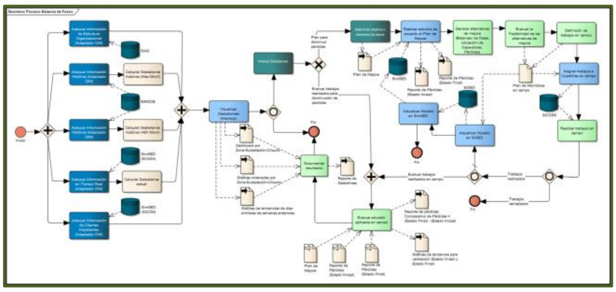

Fig. 11. The BPM diagram showing the full process to Phase Unbalance correction in the electric power distribution system.

The next benefit is about the ability to integrate new functionality, apply changes in any integrated system, even considering replacing any legacy system, having no impact on other existing systems and with no inconvenience to the user.

Finally, total time for systems integration was reduced, from many weeks to only some days and the total time for maintaining point-to-point interfaces was almost eliminated, because now CFE has the know-how about CIM philosophy, Enterprise Application Integration, SOA and standard services, as well as a robust infrastructure to support a CIM-Based Semantic Interoperability Strategy.

7 CIM-Based Solutions

Considering new capabilities, a new application was completely developed, CIM-Based using the current semantic interoperability strategy implemented at DVMC.

The main objective of the new solution is to integrate functions oriented to decision support at Distribution Control Centers for losses reduction by means of Phase Unbalance correction.

First question resolved is: Related to Phase Unbalance in Distribution feeders (Current, Real Power, Reactive Power and Voltage); which areas and feeders show the worst behaviour today?

Next figure shows the GUI for a dynamic dashboard for Phase Unbalance counting. It includes two time spans: Mobile Month and Mobile 48 Hours. Each parameter counted considers three levels and light colors code: Good, not Good and Bad.

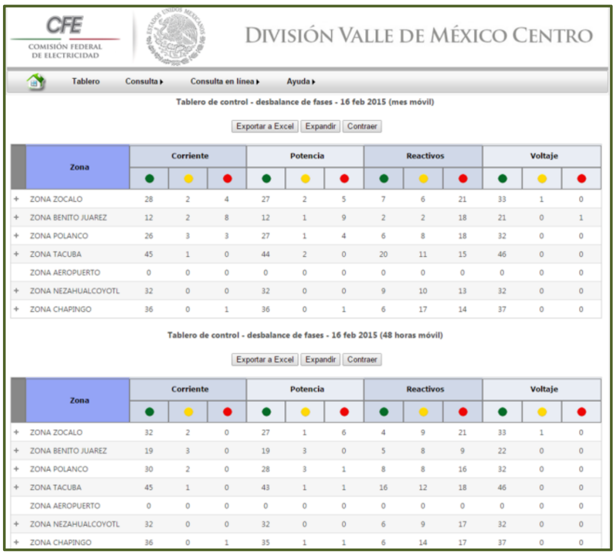

Fig. 12. Phase Unbalance dynamic dashboard.

For decision support, the analyst user can drill-down information and obtain detailed data, for example the feeders in red, average of per cent Phase Unbalance, average of Power Factor (PF) and capacitor compensation required to reach a PF>0.96.

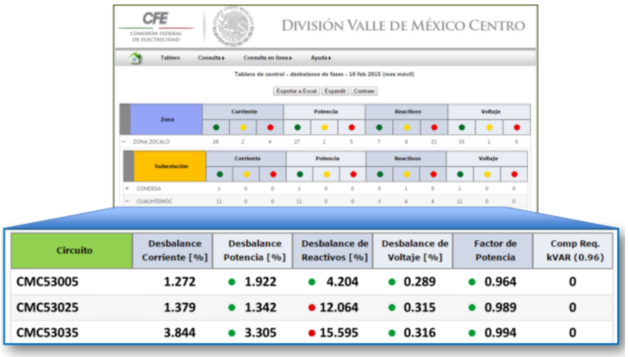

Fig. 13. Detailed information about Phase Unbalance in the same dynamic dashboard.

Next resolved question is: In a region (composed by many substations) or in a substation, how is the Phase Unbalance behaviour?

Next figure shows the average of Phase Unbalance for each feeder in a region, 4 similar graphs show each parameter (Current, Real Power, Reactive Power and Voltage) the user can reorder by each parameter and change between per cent or total magnitude. It includes three time spans: Mobile Month (Blue), Mobile 48 Hours (Orange) and Real time (Green).

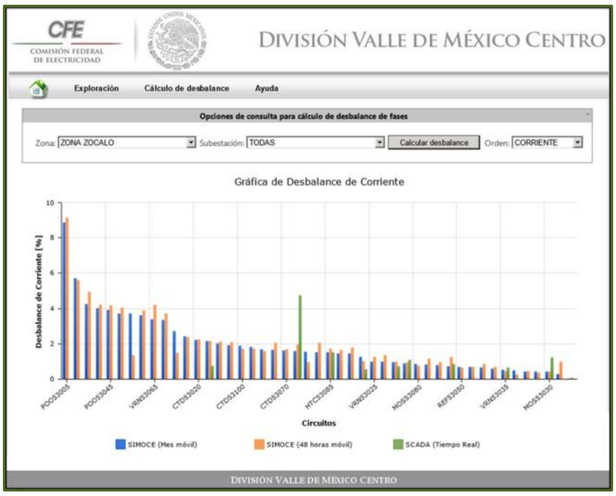

Fig. 14. Phase Unbalance for a region: Zone ZOCALO at DVMC.

Depending on user selection, the graph could show only feeders for a single substation; next figure shows the average of Phase Unbalance for Current (in percent mode), including only the feeders in a distribution substation at DVMC.

User could change criteria in order to obtain more details. Basic functions as zoom in, zoom out, panning and JPG export are included.

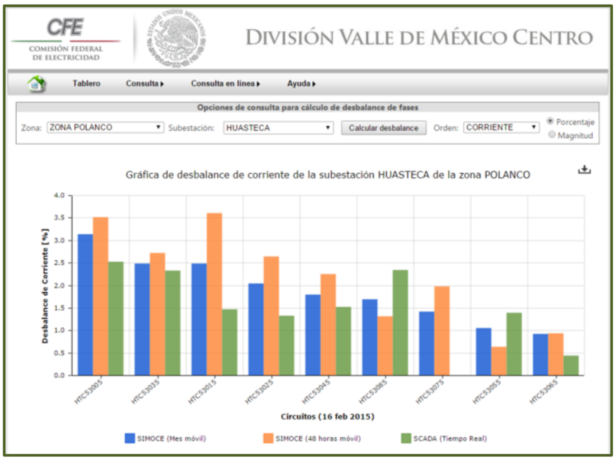

Fig. 15. Phase Unbalance for a Substation: Zone POLANCO, Substation HUASTECA at DVMC.

When a correction in the real electric power distribution system is applied, the verification of the correction is very important in order to validate field actions and their repercussions in losses reduction. The new resolved question is: How the action impacts the electric Phase Unbalance daily profile?

Next figures (Fig. 16 and Fig. 17) shows the behaviour of the daily profile for each parameter (Current, Real Power, Reactive Power and Voltage), graph can be parameterized by a previous date (more than 4 weeks before) and an additional date (between previous date + 4 weeks and now). In this graph, an analyst can compare real impacts in the electric Phase Unbalance for the same weekday, for example the 4 Mondays of the past month against the Monday of the past week.

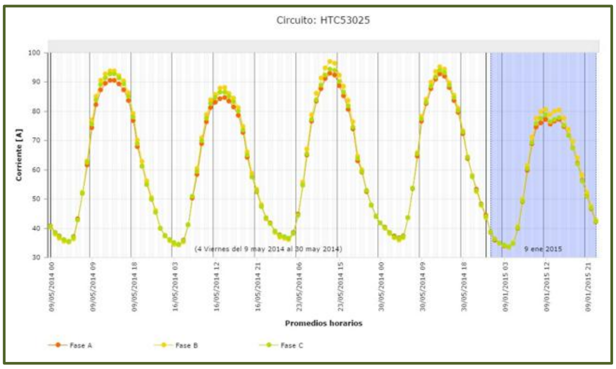

Fig. 16. Feeder daily profile comparison (Current). Zone POLANCO, Substation HUASTECA, Circuit HTC53025 at DVMC.

This profile graph shows evidence of real impact related field actions and its repercussions in losses reduction. Using this view, an analyst could verify and evaluate maneuvers for improvement the optimal operation of the EPDS.

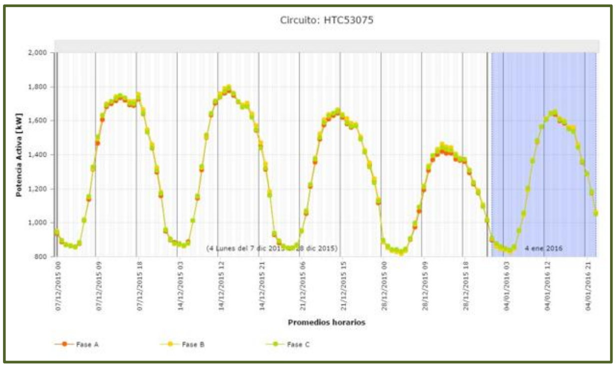

Fig. 17. Feeder daily profile comparison (Real Power). Zone POLANCO, Substation HUASTECA, Circuit HTC53075 at DVMC.

Additionally, when a failure occurs in the electric power distribution system, it is mandatory to have a data source for very important affected customers. The new question resolved is: How many and which VIP customers were affected for an event?

Next figure shows the VIP customers information associated to each feeder.

Fig. 18. VIP customers information for Circuits of Substations in Zone POLANCO at DVMC.

8 Results

Next are some of the most important results of the implemented semantic interoperability strategy for operational planning for the EPDS:

- Ability for integrate new and advanced functions. It is now available an integral view of the information related the EPDS (electrical, geospatial, topological, operational, physical, historical, etc.). New applications could be developed to obtain integral information about multiples systems using a single common language (CIM).
- Standardization implies a lower effort for development of system interfaces and maintenance in the long time.

- Change management. The strategy allows changes in legacy systems without affect the systems interfaces. Most of the changes in legacy systems will affect only the interface in the server side. The client applications don't need make changes avoiding spend money and time on maintenance.
- Improved response time for user. In all cases, the software tools developed considers a lower response time, e.g. the phase unbalance dynamic dashboard (Fig. 12) presents results in about 20 seconds for all circuits of the DVMC, manually, an analyst could obtain the same results in approximately 3 days; the graph phase unbalance for a region (Fig. 14) is showed in 40 seconds, manually an operator could obtain this graph for all feeders for a Zone in 2 days; finally, the trend for feeder daily profile comparison (Fig. 16 and Fig. 17) is showed in screen in 20 seconds as maximum each time, against 2 or 3 hours required to be generated manually each evaluation.
- Optimal Decision Support (based on information). All of the new functions were developed considering information from multiple legacy systems, all using the CIM as data model and completely focused on extract, processing, conditioning and showing information to support operational decisions at Distribution Control Centers.
- Easiness for maneuver effects validation and evaluation. The phase unbalance dynamic dashboard (Fig. 12) allows select the worst case of energy losses in feeders, then the analyst in charge of operational planning for optimization of the EPDS execute the engineering distributions functions described in Fig. 11 and define the changes required in the EPDS, a field crew make changes and immediately, the effect could be showed using graphs like in Fig. 14, after one or two days, the graphs of Fig. 16 and Fig. 17 shows the results in steady state and in a permanent way until new changes of topology is made and it is affected the phase unbalance.
- Complex calculations. The new strategy includes the ability to execute new complex evaluation, e.g. a lot of information processing for take an operational decision (Fig. 16, Fig. 17 and Fig. 18), as well as evaluation of electrical formulas for distribution engineering in order to evaluate the EPDS physical capabilities (Power Factor, Ampacity, power flow, load transfer, operational stability, reliability, energy losses, peak demand, among others).
- Easiness for historical behavior evaluation. During normal operation, an electrical event could occur (transient, fault, regional blackout, among others). The Operator must evaluate the situation in a very short time (typically less than 1 minute) and take a decision for electric service reestablishment. A basic function for decision support is to evaluate the historical behavior in the region of event influence (a circuit segment, a feeder, a substation, an area or a region). Some applications developed using the interoperability strategy includes the optimal information extraction and conditioning. An Operator can generate the graphs of Fig. 19, Fig. 20 or Fig. 21 in about than 10 seconds each or combine all in only one graph or table. Each graph shows the historical behavior for any parameter; inclusive, if the possible optimal solution considers energy transfer among feeders, a profile comparison is possible for a day, a week or any period required. Now the decision is based in historical behavior evaluation, not only in human experience.

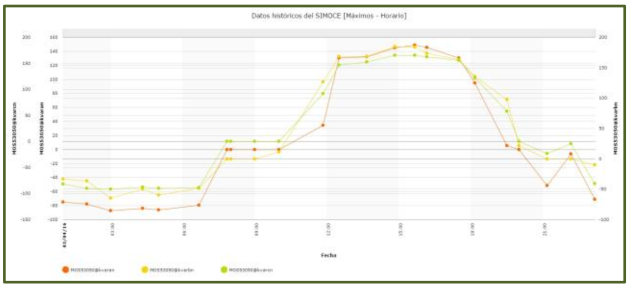

Fig. 19. One feeder daily profile (Current).

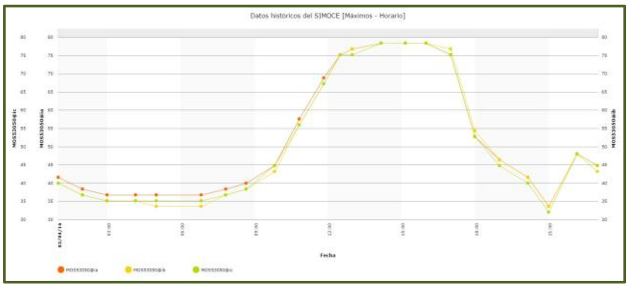

Fig. 20. One feeder daily profile (Reactive Power).

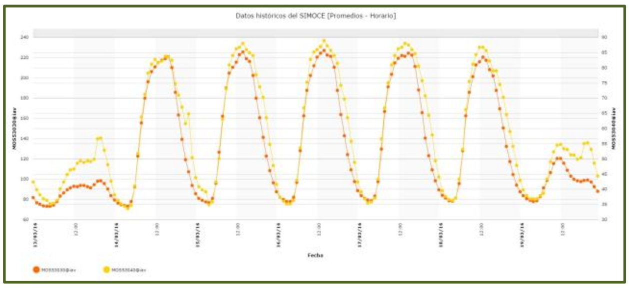

Fig. 21. Two feeders daily profile - comparison for a week (Current).

9 Conclusions

CIM adoption process is not an easy path, it is necessary to integrate a great strategy, robust infrastructure, mature standards, best practices, formal methodologies and expert people in order to reach real objectives.

Shared knowledge, experiences and results are very important for scientific community; DTE Energy proposes "Also, organized meetings and events to get multiple utilities in a room to share and develop common requirements and semantic models would have been beneficial" [2].

Experience in CIM adoption processes shows positive results in the majority of the cases because the common modelling by itself minimizes the inconsistency mistakes and duplicity of information.

Smart Grid will be a great and complex system of systems interacting together; a Semantic Interoperability strategy is an essential component for power grid modernization.

Implementing a Semantic Interoperability strategy in a utility, new advanced functions will be available to develop in a near future, such as demand side response, real time pricing and demand peak shaving, among others.

Acknowledgements

From IIE:

- Alejandro Villavicencio, Nestor Aleman and Jurgen Cruz.

From CFE:

- Jose Luis Garcia, Hector Hernandez, Raul Usla, Miguel Mendoza and Elizabeth Serna.

From SISCO:

- Margaret Goodrich.

References:

[1] Espinosa-Reza A., Calleros-Torres T.M., Torres-Espindola M.L., Aleman-Cruz N.A. and Garcia-Mendoza R., "Semantic Interoperability for Smart Grid, CIM Adoption Process", INSTICC SMARTGREENS 2014, 3rd International Conference on Smart Grids and Green IT Systems, Barcelona, Spain, 3-4 April, 2014, ISBN: 978-989-758-025-3, pp. 90-95.

[2] SGIP 2.0, "Implementing the CIM at DTE. An Implementation Methods Committee Case Study", January 27, 2014.

[3] EPRI, "IntelliGrid Common Information Model Primer, Second Edition", October 2013, Technical Report.

[4] NIST, NIST Special Publication 1108R3, "NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 3.0", September 2014.

[5] Parra I., Espinosa A., Arroyo G., Gonzalez S., "Innovative Architecture for Information Systems for a Mexican Electricity Utility", CIGRE 2012 General Meeting, Paris, France, September 2012.

[6] Espinosa-Reza A., Garcia-Mendoza R, Sierra-Rodriguez B., "Semantic Interoperability Architecture for the Distribution Smart Grid in Mexico", The 11th WSEAS International Conference on Applied Informatics and Communications AIC'11, WSEAS and IAASAT, Florence, Italy, August 23-25, 2011, pp. 204-209. ISBN 978-1-61804-028-2.

[7] Espinosa-Reza A. and Sierra-Rodriguez B., "Towards Distribution Smart Grid in Mexico", UCAIug 2011 Summit - CIM Users Group Meeting - Austin 2011, Austin, Texas, USA, November 15 – 18 2011. (http://www.ucaiug.org/Meetings/Austin2011/)

[8] GWAC, GridWise Architecture Council, "GridWise Interoperability Context-Setting Framework", March 2008 (http://www.gridwiseac.org).

[9] CIMtool (http://www.cimtool.org), February 2015.

[10] W3C, The World Wide Web Consortium (http://www.w3.org/), February 2015.

[11] OMG, Object Management Group (www.omg.org), February 2015.

[12] IEC/PAS 62559, "IntelliGrid Methodology for Developing Requirements for Energy Systems, Publicly Available Specification", Edition 1.0, 2008-01.