CIM-Based System for Implementing a Dynamic Dashboard and Analysis Tool for Losses Reduction in the Distribution Power Systems in México

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Abstract: - This paper shows the process to develop a Web Application totally CIM-Based, the standards and the development of necessary tools used to achieve the semantic interoperability between legacy systems of Comision Federal de Electricidad (CFE by its Spanish acronym) in Mexico, as well as the system functionality.

Key-Words: - Common Information Model (CIM), Semantic Interoperability, Smart Grid, Enterprise Service Bus (ESB), CIM Wrappers, Web Services Definition Language (WSDL).

1 Introduction

This paper describes a CIM-Based system for implementing a Dynamic Dashboard and Analysis Tool using historic and real-time data, in order to implement strategies for losses reduction in the Distribution Power Systems in Mexico.

There are many references that describe the Common Information Model (CIM), EPRI define "The Common Information Model (CIM) is a set of open standards for representing power system components" [1]

The CIM is defined in a group of standards, the most important are: IEC-61970-301, IEC-61968-11 and IEC 62325-301.

- The IEC-61970-301 defines the CIM Base set of packages which provide a logical view of the physical aspects of Energy Management System information. [7]
- The IEC-61968-11 specifies the Distribution extensions of the Common Information Model (CIM) specified in IEC 61970-301. [8]
- The 62325-301 establishes the extensions for the Electric Market or CME (CIM for Market Extensions).

For the development of the Dynamic Dashboard and Analysis Tool we also based on IEC-61968-100 standard which specifies an implementation profile

for the application of the other parts of IEC 61968 using common integration technologies, including JMS and Web Services [9].

There are many people around the world using CIM standards on applications. Comision Federal de Electricidad (CFE by its Spanish acronym) in the Valley of Mexico - Centre (DVMC by its Spanish acronym) is implementing a CIM-Based Semantic Interoperability Strategy for Smart Grid and the system described in this paper is a client application that uses the products developed for the Semantic Interoperability Strategy. [11], [12], [13]

1.1 Literature review

CIM is defined in [2] as "A set of standards to enable system integration and information exchange based on a common information model"; CIM provides a general information model and schemas for messages/files exchanged between systems in the electric power industry context. CIM employs a canonical data model (CDM) strategy for standardizing interfaces in the power system operations and planning domain.

In [3] is presented a novel idea using CIM in order to make the grid smart, in this way, information from a variety of intelligent equipment needs to be integrated to enable smart applications. The main interest is the use of linked data to integrate different data sources and make them easy accessible for different uses. The method proposed is an Ontology mapping.

In [4] author presents how utilities are adopting CIM for enterprise messaging and systems integration, a brief revision of the most important standards are presented and describes "CIM becomes nowadays an indispensable factor in a SOA-based business environments". Fig. 1 shows a scheme for CIM messages encapsulation using CIM standards.
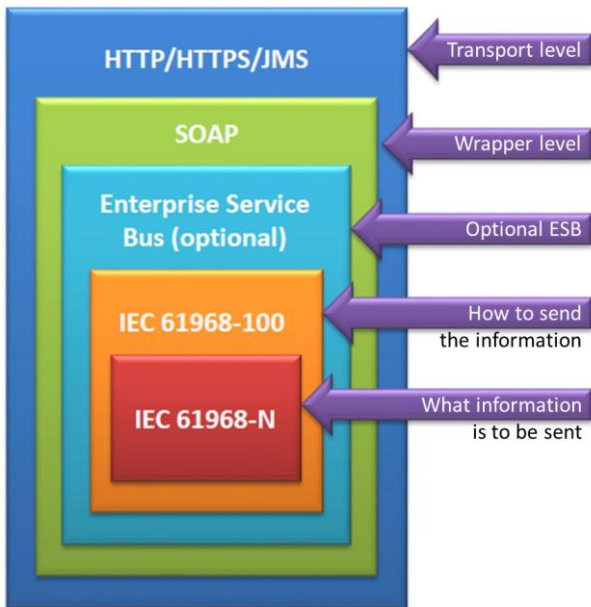

Fig. 1. Messages encapsulation in Common Message Envelope.

The Hawaiian Electric Company (HECO) presents in [5] a work for integrate three different network models. Was integrated the high-voltage planning network, the balanced medium-voltage sub-transmission network and the unbalanced low-voltage distribution network. All the processing, integration and analysis of the data itself is done in its CIM format, see Fig. 2.
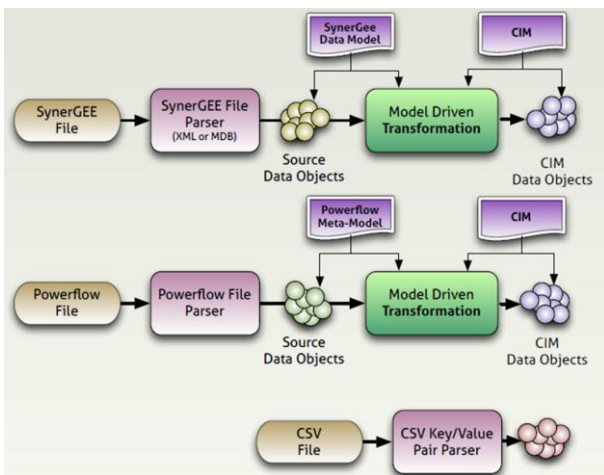

Fig. 2. Transformation process, from proprietary formats to CIM data objects.

In [6], the authors describe some CIM-based projects and logical architecture for system integrations for Slovenian Distribution System Operators (DSO's): 1. Elektro Gorenjska (long-term multiphase project), 2. Elektro Maribor (integration platform for SCADA/DMS, AM, GIS, MDMS integration), 3. Elektro Celje (DMS, MDMS integration), 4. Elektro Ljubljana (SCADA/DMS, AM integration). Additionally, some data are exchanged between actors on the Slovenian energy market: 1. DSO–Supplier–Market organizer (metering related data) and 2. DSO–TSO (operational measurements).

2 Problem Formulation

CFE has developed and acquired many information systems to maintain the information about all its business processes, for example: Generation, Transmission and Distribution operations; data monitoring and network optimization; commercialization billing and customer management; among others. These systems were generated in different moments with different technology since codification languages to database managements, and also different programming people or vendor provider. Some systems are home-made and others are from software companies.

The information integration of all the systems is very difficult because of the technologies and the proprietary data formats. To obtain information from one system to other is necessary to apply a point-to-point strategy using customized interfaces and the number of systems is increasing.

Fig. 3 shows the point-to-point integration strategy where each system needs an interface with the other systems (one interface per system); each interface is designed only for one system; if System A requires information from System B, System C, System D and System E is necessary to develop four different interfaces.
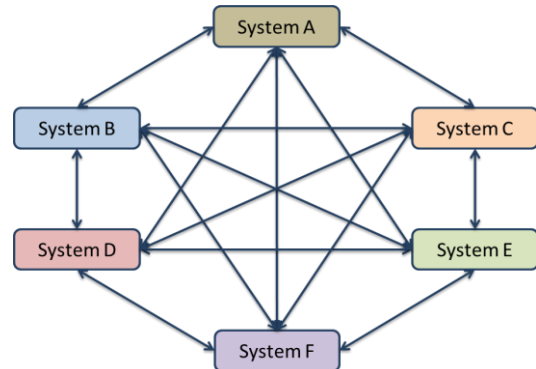

Fig. 3. Point-to-point integration strategy.

3 Problem Solution

To avoid a point-to-point integration is necessary to consider new technologies, methodologies and standards. The objective is achieving an Enterprise Architecture Integration (EAI) to replace from point-to-point links to a single link called message bus. [12]
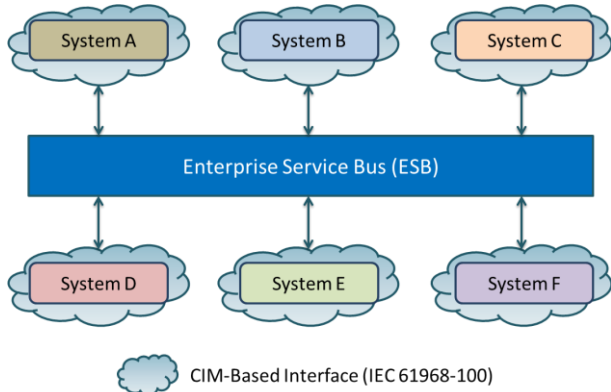

Fig. 4. CIM adoption through an ESB to solve point-to-point integration problem.

EAI involves the adoption of standards and best practices like Service Oriented Architecture (SOA), XML, Web Services (WS) and Enterprise Service Bus (ESB). But it is important to consider the adoption of a common data model to give meaning to the information exchanged. CFE has adopted CIM to solve this problem, using CIM as Common Information Model defined in IEC-61970-301, IEC-61968 -11 and IEC 62325-301, but also like a guide to develop CIM-based interfaces according to IEC-61968-100.

The complete solution and the standards used for the system developed are described in next subsections.

3.1 Operational Systems

Any utility has many systems to manage their processes. DVMC has many systems involved in the energy distribution process, the first approach to Semantic Interoperability only considers the systems that share information or those whose need information from another system and usually obtained that information with a point-to-point strategy. The considered systems are:

- SIAD – Distribution Management System.
- SIMOCE - Steady state monitoring, and energy quality supervision.
- SCADA - Supervisory Control and Data Acquisition at the Distribution Control Center.

- VIP Customers - Important Customers at Energy Distribution Grid.
- AMI/MDM - Advance metering infrastructure for customer consumption monitoring.

3.2 CIM Profile

A CIM Profile is a subset of classes, attributes and associations from the CIM Base that represent real world objects. It represents a part of CIM defined in IEC 61970-301 and 61968-11. To develop a CIM Profile it is important to consider the relationship with the processes or information systems that are essential to be exposed to another system or areas in the utility. [11]

The CIM Profile has to be one for utility and must consider all processes and information that the utility wants to get CIM compliant. The easy way to develop a complete CIM Profile is to begin developing one Profile per system or process and once that it is validated join with the complete CIM Profile in a unified way.

In this sense, there is a CIM Profile for each operational system mentioned in 3.1 that has only the classes about the information that is useful to other systems.

3.3 CIM Adapters - Server Side

The important information that is essential to other systems or areas in the utility is exposed throw CIM Adapters (or CIM Wrappers). To develop a CIM Adapter is necessary to consider that a legacy system is used by other systems and the information that user can obtain is useful information for more than one system.
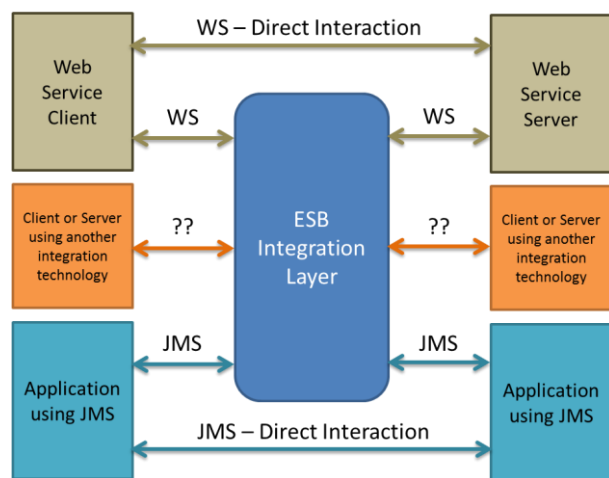

Fig. 5. IEC 61968 - Overview of scope.

The CIM Adapter is developed based on IEC-61968-100. This standard specifies an

"implementation profile for the application of the other parts of IEC 61968 using common integration technologies, including JMS and Web Services" [9]. Fig. 5 shows how IEC 61968 compliant messages are conveyed using Web Services or JMS and this communication could be through an ESB Integration Layer or directly between Web Services or JMSs.

The IEC-61968-100 describes different Use Cases from the perspective of the systems integration:

- Simple request/reply.
- Request/reply using an ESB.
- Events.
- Transactions (point to point pattern, request/reply pattern or one way pattern).
- Callback.
- Adapters.
- Complex messaging.
- Orchestration.
- Application level Use Cases.

The CIM-Based system developed uses the implementation of CIM Adapters developed according to the Adapters Use Case. This Use Case is useful when the legacy application cannot directly connect to an ESB or another application. One essential part of the system developed is the use of CIM as information model, legacy systems are not CIM compliant, and the first step to implement a solution for the point-to-point integration problem is to develop CIM Adapters that convert data between an application model to CIM. These CIM Adapters are based on the messaging standard defined in IEC 61968-100. Fig. 6 shows the use of CIM Adapters to establish communication. It is important to emphasize that "Client" and "Adapter" in the figure are CIM-Based, "Server" is the CFE legacy systems.
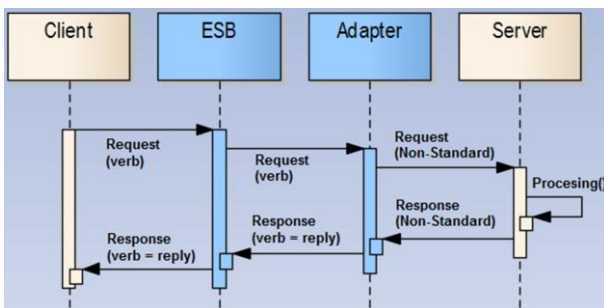

Fig. 6. Use of Adapters.

IEC 61968-100 also considers that Clients and Server could not communicate directly in that case the use of intermediaries is necessary. The Enterprise Service Bus (ESB) is used to manage those intermediaries and provides many communication patterns.

Fig. 7 shows the pattern for ESB integration to non-compliant resources, this is the used pattern for the integration of CFE legacy systems. CFE Semantic Interoperability strategy considers the use of ESB request handling via CIM Adapter.
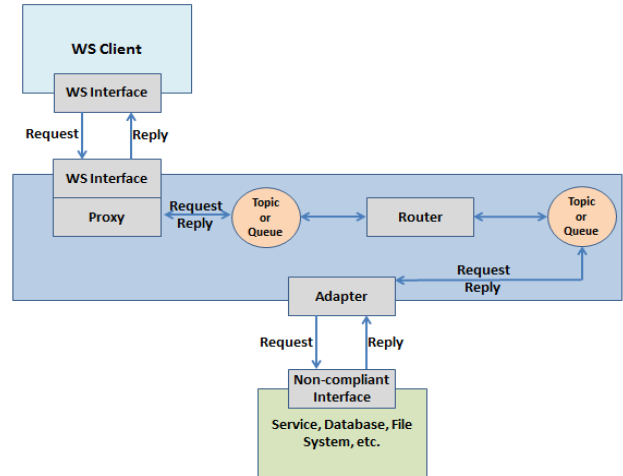

Fig. 7. ESB Integration to non-compliant resources [9].

IEC 61968-100 defines the message structure for the service interface. The service interfaces are defined using Web Services Definition Languages (WSDL) or JMS message definition or both. Also defines the XML Schemas (XSDs) that define the structure of the message payloads. The CFE CIM Adapters was developed using WSDL and XSDs for 'get' requests.

Each message has a 'verb' that indicate the operation to perform for objects of the specified 'noun'. The 'noun' is used to identify the information that is exchanged, they are also called Profiles. The CFE developed CIM Adapters were created to use the verb 'get' which is used to query for noun objects and the 'nouns' are represented by the CIM Profile classes contained in each CIM Adapter. Other component in the message is the 'payload' structure which is defined as a contextual Profile in UML. When a Client sends a request message and receive a response message it contains the information into the "payload" structure and the "payload" is composed by the CIM Profile defined for the CIM Adapter.

The common message envelope defined in the IEC 61968-100 is shown in Fig. 8 and is used in all requests to each CIM Adapter. A CIM Adapter could be a Client or a Server and the communication through them is based in this message structure.
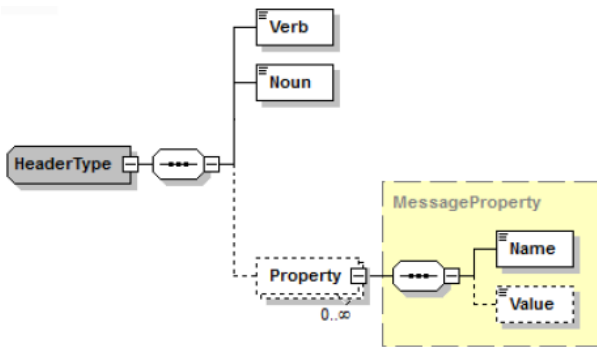
Fig. 8. Common message envelope [9].

The "Header" is the only one required for all messages and the others are optional depends on the request. Each section (Header, Request, Reply and Payload) has fields, some are required and others optional. The Fig. 9 shows the "Header" structure that CFE uses in messages.
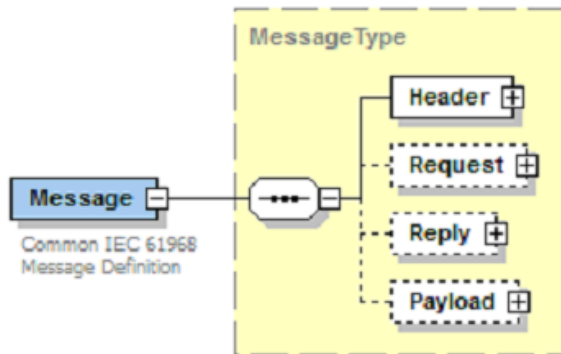

Fig. 9. Partial Header structure [9].

Request message structure has three sections, "Header" is required, "Request" and "Payload" are optional. Fig. 10 shows the Request structure used for CFE messages.
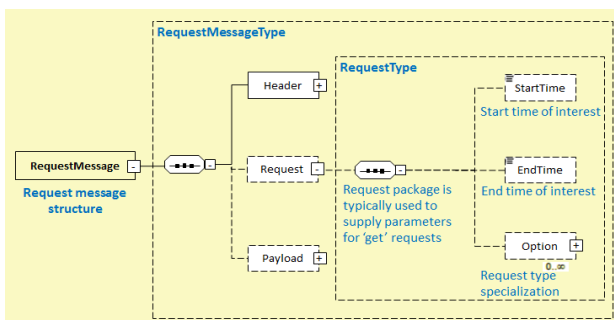

Fig. 10. Partial Request message structure [9].

The Response message structure has three sections, "Header" and "Reply" are required and "Payload" is marked as optional because depends of the information that the CIM Adapter can obtain from its own external or internal source data. Fig. 11 shows the Response message structure used for CFE messages.
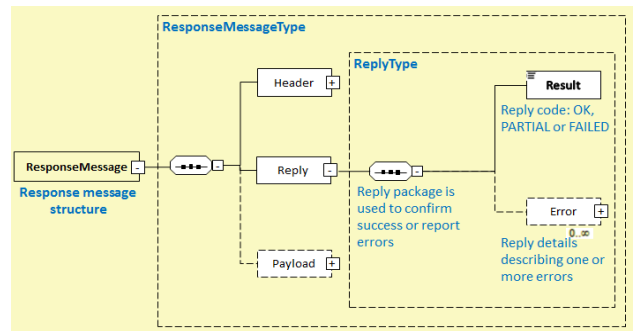

Fig. 11. Partial Response message structure [9].

3.4 CFE CIM Adapters - Functions

CFE CIM Adapters consider three types of request:

a) All Instances Request. This kind of request allows specifying which Class Client wants to know all the instances. The structure of the message sent/received to/from the CIM Adapter is:
Request message:
- Header
  - Noun: Name of the CIM Class
  - Verb: get
- Request: Not Required
- Payload: Not Required

Response message:
- Header
  - Noun: Name of the CIM Class requested
  - Verb: reply
- Reply
  - Result: Depends of the result could be OK, PARTIAL or FAILED
  - Error: There are different kind of errors defined in IEC-61968-9 Annex B, the CFE CIM Adapters return next fields:
    - code: The code is defined in the standard IEC-61968-9. If there is no error the code is 0.0.
    - reason: A description of the error defined with the code in IEC-61968-9. The description of code 0.0 is "No Errors".
    - details: Represent a free text field to describe the occurred error, for CFE CIM Adapters the "details" field is written in Spanish usually and is used to explains the cause of the error.
- Payload: Contains the CIM Classes exposed by the CIM Adapter through the CIM Profile and depending of the request, the Class requested has all the Instances found in the legacy system with the attributes in CIM.

b) Filter Request. This kind of request allows querying information filtered by one or more Class attributes defined in CIM Profile for each Class. The structure of the message sent/received to/from the CIM Adapter is:

Request message:
- Header
  - Noun: Name of the CIM Class
  - Verb: get
- Request:
  - Option: Used when name/value pairs are useful in filtering a query or to convey general or custom request options [9]. To filter information is necessary to have at least one "Option" field.
    - name: CIM attribute name of the Class requested to filter the information.
    - value: The value searched by the filter
- Payload: Not Required

Response message: Represent the same structure for response message mentioned in type request "All Instances Request".

c) Association Request: This kind of request allows querying information about Instances that are associated to an Instance from other Class. The structure of the message sent/received to/from the CIM Adapter is:

Request message:
- Header
  - Noun: Name of the CIM Class
  - Verb: get
  - Property: name/value pairs to be conveyed. The CFE CIM Adapters use this field to indicate that the request is an association
    - name: Use the word 'asociacion' (association in Spanish) to indicate that the request is for an association and the Server evaluate the Option.name field like association parameter instead of filter parameter. .
    - value: Optional value depending of the CFE CIM Adapter, only SCADA CIM Adapter uses this "value" field in order to indicate special attributes.
- Request:
  - StartTime: Start date time. Optional, only used for some CIM Adapters for historical request.
  - EndTime: End date time. Optional, only used for some CIM Adapters for historical request.
  - Option: To request an association information is necessary at least one Option field.
    - name: Association name
    - value: The ID or key value Instance to search associated Instances from other Class.
- Payload: Not Required

Response message: This section is equals than "All Instances Request", but the returned payload contains information of the associated Class.

3.5 CFE CIM Adapters – Server Side
The first approach to CIM Server Adapters for CFE was the development of the following Server Adapters:

SIAD: Contains the CFE organizational structure information like Geographical Regions, Sub Geographical Regions, Substations, Feeders and Distribution Areas. Also considers information of Customer service request like New Request, Installation Modification, Load Modification and Provisional Service Request.

SIMOCE: Contains the CIM Classes to request historical data information. It considers the steady state information for Analog values, Energy Quality Events and Meters Classes. The data layer uses OPC UA to request legacy system information.

SCADA: Contains the CIM classes to request real-time data information. This CIM Adapter exposes information for Analog values, Discrete values and Meters Classes. The data layer uses OPC UA to request legacy system information.
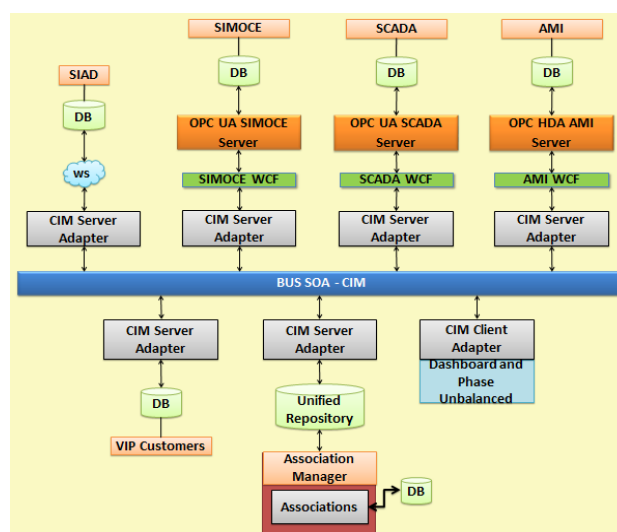

Fig. 12. CFE CIM Server and Client Adapters.

VIP Customers: Exposes information about Important Customers at CFE. Hospitals, banks, financial centers, government offices, industries facilities, department stores, etc. are consider VIP Customers. The CIM Adapter shows information like customer ID, name, address, energy demand, etc.

AMI/MDM: This CIM Adapter only contains information for Analog values and Meters Classes. The communication with the legacy system is through a data layer that uses OPC HDA.

Unified Repository: The Unified Repository is a database that contains information about systems, Classes and Instances from elements that are in different systems with different name but the element refer to the same; so this database contains a "name mapping" about these elements. This database is populated using an application for Associations Manager. The Unified Repository CIM Adapter allows querying information about the name of an element from one system to other.

3.6 Associations Manager Application

This application allows executing tasks developed as DLLs at the time and frequency that the user programs the execution, e.g. every day, every week, only once. The tasks can execute different functionalities; some of them could save information of mapping Instances in Unified Repository, others could request information from CIM Adapters and save in other database area. Next DLLs are using for CIM-Based system for implementing a Dynamic Dashboard and Analysis Tool for losses reduction in the Distribution Power Systems in Mexico:

- SIADCustomersInfo: This DLL query SIAD information about organizational structure and Customer service requests through SIAD Server Adapter. The information is saved in database in order to reduce user waiting time cause by network communication. This DLL executes every day at 00:00:00.

- SIADSimoceMapping: Query Feeders from SIAD Server Adapter, Feeders from SIMOCE Server Adapter and compares the information saved in Unified Repository database to identify the Feeders that are not there and apply defined rules to map these Feeders and save in Unified Repository database. This DLL executes every day at 01:00:00.

- UnbalanceHr: Uses SIMOCE Server Adapter to query information about Analog values obtaining the average per hour per Feeder for last 24 hours since a day before yesterday for next parameters: Current, Real Power, Reactive Power and Voltage, each one for A, B and C Phases for Phase Unbalance information; and also query average information per hour per Feeder for last 24 hours since a day before yesterday for Current, Real Power and Reactive Power for Dashboard information. This DLL executes every day at 05:40:00.

- InfoGenerationHr: Uses UnbalanceHr saved information to generate the average per hour, per day and finally per Mobile Month (28 days before a day before yesterday) and Mobile 48 Hrs (2 days before a day before yesterday). This DLL executes every day at 06:10:00.
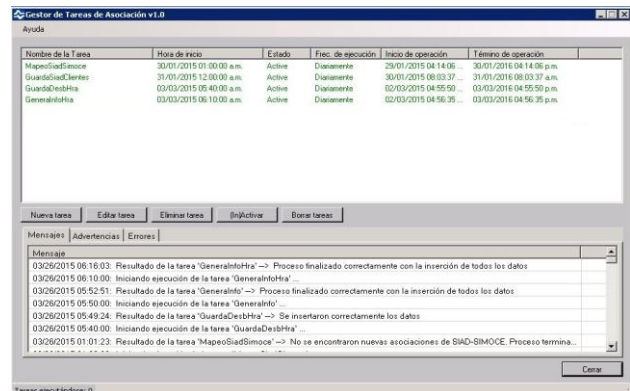

Fig. 13. Associations Manager Application GUI.

3.7 CFE CIM Adapters – Client Side

CFE had an integration problem between their systems and also had the necessity to calculate Phase Unbalance from Distribution Feeders and they want to generate a Dynamic Dashboard for Phase Unbalance counting. CFE has the knowledge about CIM and the tools to generate this Web Application totally CIM-Based using the CIM Adapters – Server Side described previously. They have implemented an Interoperability Strategy CIM-Based and developing a Client Application CIM-Based to solve the problem demonstrates the importance, benefits, information availability and the facility to integrate their systems CIM-Based through an ESB, saving development time, maintenance time for point-to-point integration, human resources and money resources because the Application allows analysis strategies for energy losses when the user detects which Feeder has a problem and can execute a Phase Unbalance correction.

Fig. 14. CIM-based system for implementing a dynamic dashboard and analysis tool for losses reduction GUI.

Fig. 15. Phase Unbalanced Dynamic Dashboard for a Mobile Month.

3.7.1 Database Query vs. On-line Query

In this CIM-Based system exists two options to query information "Database Query" and "On-line Query".

Database Query has the Dynamic Dashboard, CIM Exploration and Phase Unbalance functions. The information of these functionalities was obtained through a local database query and the information of that database is from the daily execution of SIADCustomersInfo, UnbalanceHr and InfoGenerationHr Associations Manager DLLs. The objective of this type of query is to reduce the time to respond a request because of the latency of the network.

On-line Query allows realizing CIM Exploration, Phase Unbalance and Feeder daily profile comparison. The difference is that in this case the queries to obtain the information are directly to SIAD CIM Adapter, Customers VIP CIM Adapter, SIMOCE CIM Adapter and Unified Repository CIM Adapter to know the name of Feeders in SIMOCE from SIAD, all these through an ESB not to a database and the Phase Unbalance calculations are on the fly.

3.7.2 Dynamic Dashboard

It is a Dynamic Dashboard that shows the counting of Feeders that exceeds Phase Unbalance limits for Current, Real Power, Reactive Power and Voltage. Depending on Unbalance they are classified with colors green (good), yellow (not good) and red (bad). The analyst user can navigate to Area, Substation and Feeder and see the percentage of Phase Unbalanced, average of Power Factor (PF) and Capacitor reactive compensation required to reach a PF > 0.96. The information showed is for a Mobile Month and Mobile 48 Hours.

The Dynamic Dashboard information is obtained through a database. This database was populated using UnbalanceHr and InfoGenerationHr Associations Manager DLLs. The Power Factor and Capacitor reactive compensation required are calculated on the fly based on standard formulas with the database information.

3.7.3 CIM Exploration

Allows exploring organizational structure from SIAD until Feeders; depending on the request the user can obtain CIM information, Customer service requests information or Customers VIP information.

CIM information option shows the CIM attributes information for each instance selected in the tree.

Customer Service option shows the CIM attributes information for the service and the related information from customer like name, e-mail, phone number, this information only can be requested on CFE_Zone instance.

The figure below shows information about VIP Customer. This information can be requested on CFE_Circuit instance.

Fig. 16. VIP Customers information.

3.7.4 Phase Unbalance

User can select showing the Phase Unbalance for each Feeder from a Region or from a Substation. The obtained information is four graphs for each parameter Current, Real Power, Reactive Power and Voltage. Each graph contains the Phase Unbalance for each Feeder with three time stamps Mobile Month is a blue bar, Mobile 48 hours is an orange bar and Real Time the green bar that is obtained on-line from SCADA CIM Adapter. User can select to see the information in percent or total magnitude mode, as well as can select the parameter to sort values from the worst case to the better; this function allows identify rapidly which circuit requires special attention and how the correction will impact in the network.

Fig. 17. Feeders Phase Unbalance for a Substation.

Using the information of the CIM-Based system developed, an expert user in the Distribution Control Center can take an informed decision of which Feeder analyze in detail to obtain the best impact in the actions applied in the real Distribution Power Systems. This system is joined to other software tools like the On-Line Simulator [13] to maximize results and minimize uncertainty in actions programed for energy losses reduction.

3.7.5 Feeder daily profile comparison

This functionality only can execute on-line and allows knowing the behavior of the daily profile for Current, Real Power, Reactive Power and Voltage, the information is requested from SIMOCE CIM Adapter through the ESB. User must choose one previous date considering at least more than 4 weeks before and additional date between previous date and one day before today. This information is relevant because user can compare real impacts in the electric Phase Unbalance for the same weekday and shows the real impact of the actions taken in losses reductions.
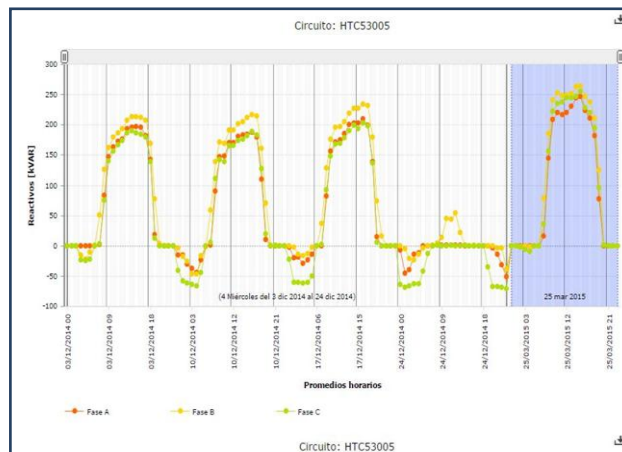

Fig. 18. Feeder daily profile comparison.

4 Conclusions

The path to achieve the CIM adoption is not easy, the utilities have to allocate resources to learn, develop, test, migrate and buy hardware and software to the adoption. Migrate legacy systems to CIM philosophy represents a great effort principally to change the development mentality; the utility has to accept the change and begin to implement standards CIM-Related in their processes. The learning line is long but the final results are amazing.

The utilities can share information between their systems, only need to develop one interface per system to obtain information from others systems even other CIM-Based utilities, but is important to consider that there must be a single CIM Profile for all the utility, guarantee governability, avoid duplicity, inconsistency and incompatibility, keep attached to the standard to achieve a Semantic Interoperability.

The results at CFE allow confirm that CIM adoption has positives results, minimize the system interfaces development and maintenance, let to achieve a Semantic Interoperability, facilitates systems communication and allows developing CIM Adapters – Client Side that represent an integral solution to obtain information about multiples CIM Adapters – Servers Side.

The Interoperability Strategy allows changes in legacy systems without affect the CIM Adapters – Client Side. Depending on changes in legacy system the affected could be the CIM Adapter – Server Side but only on data layer because is the only one that have direct relationship with legacy system model. This is an advantage because the applications related don't need changes avoiding spend money and time on maintenance.

This system and its Interoperability Strategy is focused in time optimization, profitability, productivity and cost saving for utility in terms of user visibility, agile information analysis, optimal information exchange, ability to implement new and advance functions, systems synergy and minimization of interfaces maintenance.

Future work is focused in more enterprise systems integration, like OMS, CRM, DMS, MWFM, among others, in order to obtain more benefits of this strategy; additionally, Business Process Management (BPM) will be used to integrate a modeling strategy, next solution under definition implies an integral management of failures and software tools for analysis and prevention as well as, a multidimensional database for OLAP.

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