Semantic Interoperability for Smart Grid
CIM Adoption Process

Alfredo Espinosa-Reza, Tito Manuel Calleros-Torres, Marxa Lenina Torres-Espíndola, Nestor Adrian Aleman-Cruz and Raul Garcia-Mendoza
Instituto de Investigaciones Electricas, Reforma 113, Col. Palmira, Cuernavaca, Morelos, Mexico

Keywords: Smart Grid, Common Information Model (CIM), Semantic Interoperability, Distribution Management.

Abstract: This paper describes the experience obtained in the adoption process of the Common Information Model (CIM) as part of definition of a strategy for semantic interoperability for legacy information systems of *Comision Federal de Electricidad* (CFE by its acronym in Spanish). The strategy and the process described are supported by standards IEC 61968 and IEC 61970, as well as best practice in software development in the international context. Overall, the architecture for interoperability and the adoption process, will establish a solid infrastructure designed to meet Smart Grid requirements for management systems for the Electric Power System (EPS) in Mexico. Some results are discussed.

1 INTRODUCTION

The electric market deregulation in USA, Europe and several countries in the world, as well as emergent technologies required to establish the vision of Smart Grid have increased the need of the electric utilities to exchange information in a daily way, thus, overall they must ensure the reliability of the operation of interconnected electric systems.

Likewise, all electric utilities uses internally a great quantity of formats and technologies for systems and functions for manage the electric power system, considering data storage in several databases (hierarchical, relational, object oriented, geospatial) and files in custom formats, as well as operating systems of any kind and supplier, even though being incompatible among them.

In this way, it has become exponential the problem of develop and maintain updated a great quantity of data interfaces, many processes for exporting and importing information, as well as several requirements to transform the exchanged data, all of this coupled to a typical problematic: the information and function **duplicity**, that happens when two or more systems contain the same data or perform the same function; the data **inconsistency** is evident when two systems have different values for the same data; and the **incompatibility** that occurs when the information of two or more systems, it cannot be combined for technological causes, political, syntactical or semantic (Parra et al., 2012).

Smart Grid will be a great set of systems of interconnected systems (electric and computerized), thus being every time more evident the necessities of interoperability of the information systems in charge of monitoring, control and manage, overall, due to the advanced functions that are being defined, establish as a premise the capability of information exchange in agile and expeditious manner.

2 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 (NIST, 2012).

According to the reference framework defined by the GridWise in (GWAC, 2008), the informative interoperability covers the content, the **semantics** and the data format or instruction flows (as are the accepted meaning of human beings and programming languages). It focuses into which information is exchanged and its **meaning.** It establishes the understanding of the contained concepts in the data structures of exchanged

Espinosa-Reza A., Calleros-Torres T., Torres-Espíndola M., Aleman-Cruz N. and Garcia-Mendoza R..
Semantic Interoperability for Smart Grid - CIM Adoption Process.
DOI: 10.5220/0004870800900095
In *Proceedings of the 3rd International Conference on Smart Grids and Green IT Systems* (SMARTGREENS-2014), pages 90-95
ISBN: 978-989-758-025-3

messages, and integrates knowledge of the business related to the semantics or meaning in the work flow of a process. For the first time, the exchanged data are associated to the electric infrastructure of the enterprise and rules are established that ensure that the exchanged data meet the semantic definitions established in an Information Model, being general and independent of technological platforms, systems, brands or suppliers.

The Common Information Model (CIM) is a generic Model, open and standard that can be adopted by any enterprise. CIM is defined in a group of standards of the IEC, being the most important: IEC 61970-301 which defines the Model 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 and IEC 62325-301 that establishes the extensions for the Electric Market or CME (CIM for Market Extensions). Figure 1 shows these three standards as UML packages in *Enterprise Architect*.

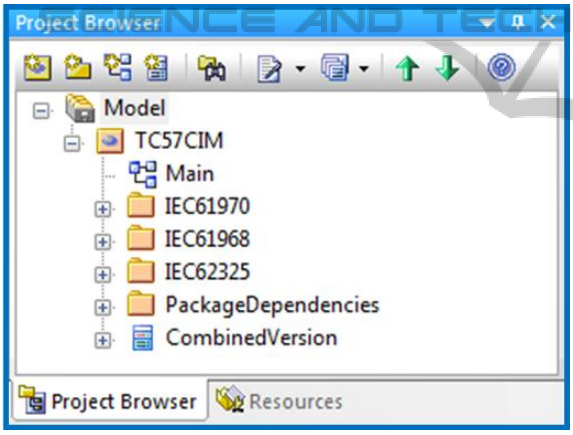

Figure 1: CIM packages in UML.

CIM have three primary uses: to facilitate the exchange of power system network data between organizations, to allow the exchange of data between applications within an organization, and to exchange market data between organizations. (EPRI, 2011).

2.1 CIM History

The CIM is a set of open standards for representing power system components originally developed by the Electric Power Research Institute (EPRI) in North America and now a series of standards under the International Electrotechnical Commission (IEC). (EPRI, 2011).

CIM was started in 1992 as part of the Control Centre API (CCAPI) of EPRI; from 1993 to 1996 it was developed with main target of allowing the use of compatible applications in order to protect the investment of the enterprises (E-R diagrams in MS-Visio were used and MS-Access as Database); in 1996 the CIM was transferred to the IEC, to the 57 Technical Committee (TC57) and 13 and 14 working groups (WG13 and WG14), the Transmission and Distribution areas were covered (UML was adopted as modeling language and it was kept in Rational Rose); in 2000 the first interoperability test was performed; in 2003 the CIM for Market Extensions (CME) development was initiated, followed by the models for Planning and Dynamics, currently the model for Weather and HDVC cables are in development; in 2005 the first version of IEC standard 61970-301 CIM Base was emitted and the CIM Users Group (CIMug) was established; in 2008 the CIM was formally adopted by the Union for the Coordination of the Transmission of Electricity (UCTE) in Europe; in 2009 the National Institute of Technology and Standards (NIST) identifies the CIM as two of the five key standards for the interoperability of the Smart Grid; in 2010 the European Network of Transmission System Operators for Electricity (ENTSO-e) migrates to CIM and sponsors the first CIM interoperability test in Europe; in 2011 in EDF interoperability tests were applied to parts IEC 61968-4 and IEC 61968-13 that define the Common Distribution Power System Model (CDPSM). Nowadays, CIM is maintained and distributed in UML with format of *Enterprise Architect* software tool.

In the Smart Grid context, in order to achieve the interoperability of the information systems in the electric utilities, several levels as well as schemes of reference have been defined, which allow to establish the strategy and enterprise architecture in order to achieve the vision. In (GWAC, 2008) a conceptual reference model is defined for the standard identification and necessary protocols in order to ensure the interoperability, the cyber security and define architectures for Smart Grid systems and subsystems; in (NIST, 2012), is defined a framework for architecture and standards for Smart Grid; in (Parra et al., 2012) is proposed an architecture for information systems of the electric utility in Mexico; and in (Espinosa and Rodriguez 2011) it is established the architecture of semantics interoperability for the Smart Distribution Power Network (SEDI by its acronym in Spanish) for CFE's Distribution Management Systems (DMS).

2.2 CIM Description

CIM is an Information Model that applies the paradigm "Object Oriented" 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. The model is constituted by: Classes Packages, Object Classes, Attributes and Relations among Classes/Objects. The model defines the interfaces for systems integration and besides, it includes the connectivity of the electric system, thus facilitating the united exchange of data among systems and enterprises.

2.3 CIM Wrapper Description

A data interface that complies with CIM is known as "CIM Wrapper" and it must allow the reading/writing of messages or XML files, its information structure meets the syntactic, semantic and electric rules defined in CIM, thus ensuring that the receiver system of a CIM message will be able to read the content (syntactic) and will be able to interpret its meaning (semantic) in an identical way as to the transmitter, without the need to know the internal data structure of the source system and in an independent manner as to its technological platform, brand or supplier.

A "CIM Wrapper" is in charge of:

- Implementing the data access of the legacy system.
- Performs the data transformation according to the Concept Map and defined Semantic Model.
- Implementing functionality in order to exhibit information to other systems.
- Taking and interpreting the information from other systems for internal use.

3 CIM ADOPTION PROCESS

Due to its complexity and initial cost (in time and effort), the adoption of CIM in an electric utility it must be part of a long term integral strategy as part of the Vision and Technological Roadmap for Smart Grid. The systems that will be bound must be defined, as well as the more convenient adoption strategy. It is recommended that the initial scope is limited but challenging, meaning by this that the information that is to be transferred is not trivial, that it is coherent and that it considers or represents complete or integral concepts, thus giving a better experience to the development group that participates in the process.

A CIM adoption strategy, overall for integrating legacy systems, it is through the development of "CIM Wrappers", which must have perfectly defined its particular scopes. In Figure 2 it is shown the adoption process of CIM based in the development of "CIM Wrappers".

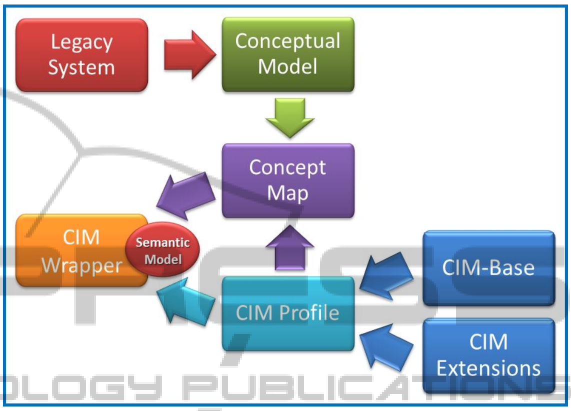

Figure 2: CIM Adoption Process based on "CIM Wrappers".

The first phase in the CIM adoption process, it has two parallel tasks: the creation of a **CIM Profile** and the development of a **Conceptual Model** of the Legacy System to integrate.

A **CIM Profile** is a subset of Classes, Attributes and Associations of **CIM Base Model** that represents the components of the real world selected for its use in the information systems. The **CIM Profile** is obtained by selecting only the concepts and its relations with other concepts that will be used in a scheme or architecture of semantic interoperability for an electric enterprise. For the concept selection and its relations it is used the software tool CIMtool (CIMtool, 2013) and the result must be obtained as Ontology in a format legible by computer, for example OWL or RDFS (Scheme) (Espinosa et al., 2011).

The **CIM Profile** can use native concepts of the CIM Base Model or the extended concepts during the **Concept Mapping.**

The **Conceptual Model** of a legacy system is a Model that formally represents the elements that compose it and the relations among them; according to the legacy system, this Model must be preferably created using the paradigm "Object Oriented" and UML, but in occasions, the relational model can be applied. This Model is the source of base information in order to know the meaning of the

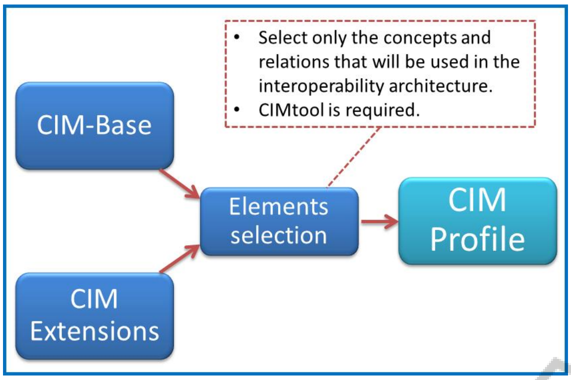

Figure 3: CIM Profile definition.

stored data and managed by the legacy system and it will allow performing the next stage.

The **Concept Map** refers to the relations among defined concepts in the **CIM Profile** and the stored concepts by the legacy systems, meaning by this that it describes the “translation rules” of the data to be exchanged. Figure 4 shows the process to define the **Concept Map**.

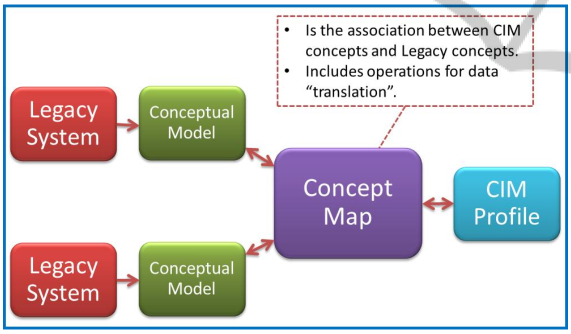

Figure 4: CIM Concept Map definition.

For example, the concept “Distribution Division” stored in the legacy systems in a table of a relational database, it can be translated in a direct way to “GeographicalRegion” of CIM, due to the fact that the CIM description establishes in a rigorous manner the definition of this Class and it corresponds to the “Division” hierarchy in the organizational structure of the enterprise. The concept “Distribution Zone” can be translated in a direct manner to the CIM concept “SubGeographicalRegion”. Likewise, the relation among these two concepts of the enterprise adequately corresponds to the defined relation in CIM for this structure, due to the fact that a Division is composed by Zones and Zones must belong to a Division.

In the case that CIM does not consider a specific concept, it is required to define a CIM extension, without affecting the **CIM Base Model**, meaning by this that without altering Classes or Relations among them. For example, the attribute “Territorial extension” of a Zone, it could be mapped to an extension in CIM through a new Class inherited from “SubGeographicalRegion” which includes all the attributes that were not identified in the **CIM Base Model**.

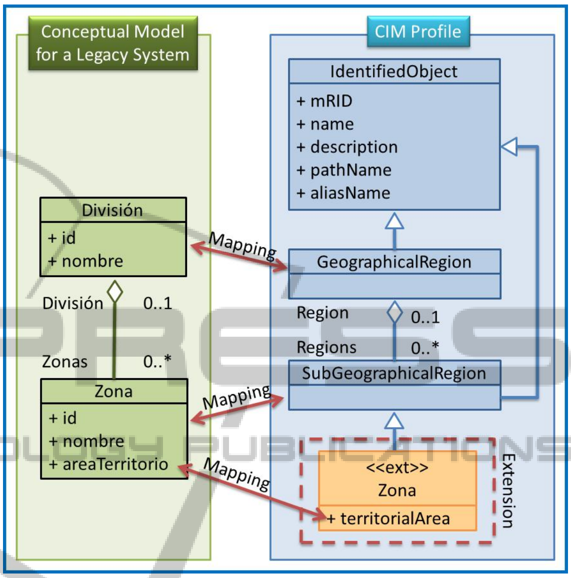

Figure 5: Example of Concepts Mapping between a legacy system and CIM.

Figure 5 graphically shows the way in which it must perform the **Concept Mapping** among the **Conceptual Model** of the legacy system and the concepts in the **CIM Profile** defined for the electric utility. It must stand out the fact that before deciding to include a CIM extension, all the resources must be exhausted in order to identify the concept in the native CIM Classes, because any extension will perfectly be managed by the internal systems that know the specific **CIM Profile**, but any entity, enterprise or system that comply with the **CIM Base Model** it cannot interpret the meaning of the extensions due to the fact that the specific extensions are not included in the standards emitted by the IEC.

Due to the relevance of the **Concept Map**, it is recommended to use a table that allows to establish the relations for the concepts translation among the legacy systems and CIM, in such a way that it serves as a tool of implementation of the meaning of information (in bidirectional way), as well as defining agreements among the development groups and maintenance of the information systems.

In case that the legacy system does not have a **Conceptual Model** and the description of the information that it contains, this table can be taken to document the formal definition of each data to exchange. Likewise, if a specific data is duplicated among different systems, this table must establish the only source as origin of this data to keep consistency of the information and thus avoid a problem of duplicity to the interoperability context that is being implemented.

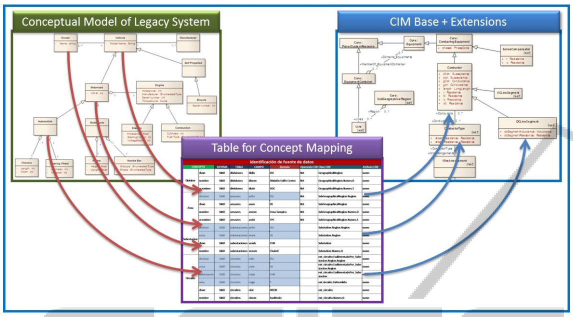

Figure 6: Table for Concept Mapping between legacy systems and CIM.

Due to the fact that CIM models the concepts that represent object of the real world of the electric utility, it is required to have the **Semantic Model** of data to share, thus it must have the explicit meaning of each data and value, as well as the relations among this data, this conceptual description must be exhaustive and rigorous with the purpose of facilitating the communication and the information exchange among different systems.

In CIM adoption process, the **Semantic Model** is obtained from the union of two artifacts, the **Concept Map** and the **CIM Profile** as shown in Figure 7.

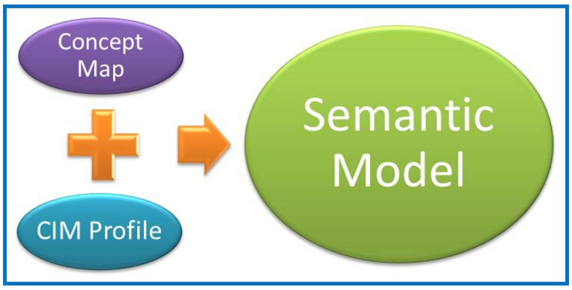

Figure 7: Definition of a Semantic Model – CIM based.

In summary, the development of a "CIM Wrapper" for a specific legacy system will use (or it will be based in) the **Semantic Model**.

3.1 Conceptual Model

The legacy system must expose the concepts that it stores or manages through its **Conceptual Model**, it must establish the meaning of each data to share and it must be the only source for these concepts in all the interoperability context and scheme scope. It must not define more than one information source for a same concept.

3.2 Concept Map

The **Concept Map** of legacy systems with the concepts in **CIM Profile** established in the mapping table, it will allows to perform the syntactic and semantic translation of transported data among information systems in both ways, from the legacy system to CIM, and from CIM to legacy systems.

3.3 CIM Profile

The **CIM Profile** will contain the common definition, strict and exhaustive, of the information to exchange among systems through CIM. It is based in the **CIM Base Model** and the concepts extensions (exclusive for a specific utility). It must be in a legible format for computer because the "CIM Wrapper" must completely implement it in Classes of some Object Oriented Programming (OOP) language for validation, reading and interpretation of the contained information in messages or files.

3.4 Completeness

The **Concept Mapping** can only use completely described concepts in the **Conceptual Model** of the legacy system and in the **CIM Profile** because in the case of accepting a non described concept, this could be ambiguous or without common interpretation of its meaning.

4 RESULTS

Next, some results obtained from applying the CIM adoption process to CFE legacy systems are described.

Figure 8 shows three views of a **CIM Instance** (real world data) with the organizational structure of the Distribution Subdirection of CFE. The left box shows a hierarchical tree that allows to navigate the components of a Division and its Distribution Zones. The right box shows the CIM segment that models these concepts and its relations. Finally, the below box shows in XML format the same data, where it is out stood that the "Distribution Division" is associated to the "GeographicalRegion" Class and "Distribution Zones" is associated to the

"SubGeographicalRegion" Class. In the example, the "Polanco" and "Tacuba" Zones are part of the "Valle de Mexico Downtown Division" (DVMC by its acronym in Spanish) and an only identifier (in red) is used to establish the association. This information comes from the Integral System for Distribution Management (SIAD by its acronym in Spanish).

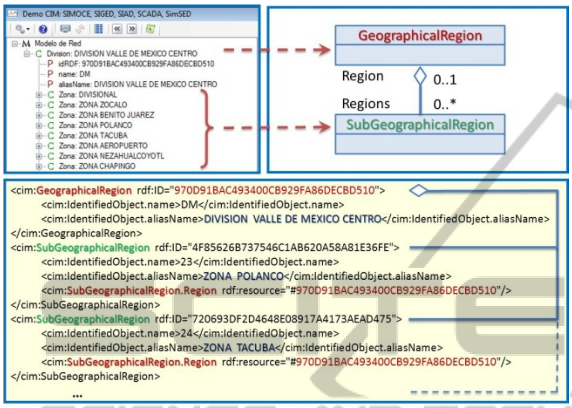

Figure 8: Different views of a CIM Instance for organizational structure in Distribution Subdirection.

Figure 9 shows that when navigating in the hierarchical tree, the **CIM Instance** allows to consult the electrical information of a Transformer of "Veronica" Substation, as well as connectivity topology and geospatial location, which comes from the GIS for Distribution Network and the electric details from the On-Line Simulator for Distribution Power Systems (Espinosa et al., 2010).

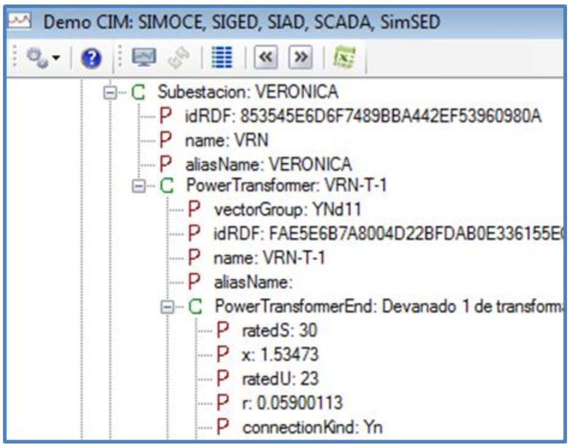

Figure 9: CIM Instance showing electrical parameters of the main power transformer in a Distribution Substation.

The application developed allows consulting multiple systems and sources of real information, without inconveniences for the user.

5 CONCLUSIONS

The adoption of CIM and an architecture of semantic interoperability are key elements that will allow the information exchange in a standard manner among systems, with the purpose of establishing advanced applications that take advantage of this capacity, such as Demand Response, Advanced Distribution Automation, Self-Healing, among others that are emerging and being defined in the international environment.

Some of the most important electric enterprises in the world are migrating their data interfaces to CIM as part of an integral vision of enterprise degree. Experience shows positive results in the majority of the cases because the common modeling by itself minimizes the inconsistency mistakes and duplicity of information.

REFERENCES

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

NIST, NIST Special Publication 1108R2, "NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 2.0", February 2012.

IEC-EPRI, IEC/PAS 62559, "IntelliGrid Methodology for Developing Requirements for Energy Systems", Publicly Available Specification, Pre-Standard, Edition 1.0, 2008-01.

EPRI, "Common Information Model Primer", First Edition, November 2011.

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.

Espinosa-Reza A., Garcia-Mendoza R, Sierra-Rodríguez 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.

Espinosa-Reza A. and Sierra-Rodríguez 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/).

Espinosa-Reza A., Quintero-Reyes A., et al., "On-Line Simulator for Decision Support in Distribution Control Centers in a Smart Grid Context", WSEAS Transactions on Systems and Control, Issue 10, Volume 5, October 2010, ISSN: 1991-8763.

CIMtool (http://www.cimtool.org), February 2013.