Electric Utility Enterprise Architecture to Support the Smart Grid
Enterprise Architecture for the Smart Grid

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Abstract: Smart grid is the new tendency for the Electric Public Utilities. The Smart Grid concept means the total automation for all processes of the EPU. For implement Smart Grid in an EPU are necessary to define enterprise architecture. The enterprise architecture to meet Smart Grid requirements for management systems for EPU in México is presented in this paper. The architecture shows layers of abstraction in the main process: generation, transmission, distribution and energy control and includes automation and control systems at all levels, from plants and substations control systems to corporative intelligent centre, including the operating centre and the energy trading system. Some results and experiences are discussed.

1 INTRODUCTION

Nowadays the Electric Power Utilities (EPU) are undergoing radical changes in the way they operate, mainly by the electric market deregulation in several countries in the world. This means that EPU must modernize its processes. This modernization enables the extensive use of information technologies based automation to maintain grid stability and to enable modern grid features such as demand side management, distributed generation, real-time pricing, and automated meter activation and reading.

Smart grid is the term commonly used to refer to an electrical grid whose operation has been transformed from a twentieth century analog technology base to the pervasive use of digital technology for communications, monitoring (e.g., sensing), computation, and control. Smart Grid incorporates information and communications technology into every aspect of electricity generation, delivery and consumption in order to minimize environmental impact, enhance markets, improve reliability and service, and reduce costs and improve efficiency.

The Carnegie Mellon University has proposed a Smart Grid Maturity Model (www.sei.cmu.edu). The model provides a framework for understanding the current state of smart grid deployment and capability within an electric utility, and it provides a context for establishing future strategies and work plans to meet the challenges of grid modernization. The model is composed of eight model domains that each contain six defined levels of maturity, ranging from Level 0 (lowest) to Level 5. The figure 1, shows the eight domains:

Figure 1: The SGMM´s eight domains.

The Technology (TECH) domain represents the organizational capabilities and characteristics that enable effective strategic technology planning for smart grid capabilities and the establishment of rigorous engineering and business processes for the evaluation, acquisition, integration, and testing of new smart grid technology. In the Technology domains raises the need for enterprise architecture.

This paper describes the design and development of enterprise architecture to support the smart grid in an EPU. The considers the adoption of standards and best practice such as BSC for strategic plan, BPM

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for the business process, IEC 61968 and IEC 61970, which define the common information model (CIM), the IEC 61850 for substation automation, IEC 62351 for security information, COBIT (Control objectives for information and related technology) and ITIL (information technology infrastructure library) for IT governance. Also uses the framework developed by the National Institute of Standards Technology (NIST) as reference for the domains and interactions between domains; the IntelliGrid architecture developed by Electrical Power Research Institute (EPRI) for the functional definition (EPRI, smartgrid.epri.com); and the interoperability framework proposed by GridWise Architecture Council (GWAC) (The GridWise Architecture Council, 2008).

2 NEED FOR ENTERPRISE ARCHITECTURE

In recent years there has been a remarkable growth of information systems; it is common in large companies to have hundreds of information systems that cover a wide range of needs. This dizzy growth over the time has resulted in what is referred as an "accidental architecture" (Giroti, 2009), which is an architecture that is built as they are covering specific needs without taking into account interoperability requirements. This accidental architecture is not necessarily dysfunctional, may be functional to a certain degree because there is availability of information among some systems or even could allow some level of integration with new systems. However, the absence of planned integration architecture increases significantly the complexity, well as information management problems and therefore it is logical to imagine that sooner or later you have technical problems of integration.

There are many needs to integrate information among different systems (CISCO Systems, 2011). The major problems are inherent to the fact of having a big group of information systems that meet specific needs without covering interoperability requirements; this situation is a normal situation in many companies in the world. Typical problems that distinguish most of the legacy systems of large companies are (Mejia-Lavalle and Arroyo-Figueroa, 2010):

- **Duplicity:** can happen when two or more systems contain the same data or perform the same function or goal.
- **Inconsistency:** happen when the same data has different values in two or more information systems.
- **Incompatibility:** happen when information from two systems cannot be combined by technological, syntactic or semantic constraints.

These problems have many consequences that impact the company's business, duplicated investment, lack of precision, duplicated effort in the capture and validation, unavailable information, difficulty to consolidate indicators, inability to relate information to make strategic decisions, etc. In conclusion, there is a great opportunity for efficiency and effectiveness in managing enterprise-level information from field devices to enterprise architecture. Additionally, there are 3 main reasons to propose enterprise architecture for integrating business systems:

The need to integrate applications: There must be a clear need to integrate business applications. It requires more flexible management indicators, preferably automated and avoids duplication, inconsistencies and unavailability of information.

Heterogeneous environments: When you deal with many different technologies, platforms and protocols, and we need to have a central solution to meet these challenges. According to an analysis (The GridWise Architecture Council, 2008), an EPU has a thousand information systems. There are information systems that have been integrated using tightly coupled interfaces, based on their own platforms and technologies which they were developed.

Cost reduction: All organizations focus their efforts to help minimize costs to maximize profits. The indirect cost involved to maintain unplanned integration architecture is reflected in resources, licenses, personnel, maintenance, support, time, etc. An integration architecture based on an enterprise bus have a strong impact on cost minimization, in addition to the benefits of higher availability of information and greater interoperability between existing systems.

3 DESIGN OF ENTERPRISE ARCHITECTURE

Architecture has two meanings according to TOGAF (The Open Group, 2009): (1) "A formal description of a system, or a detailed plan of the system at component level to guide its implementation" and (2) "The structure of components, their inter-relationships, and the principles and guidelines governing their design and evolution over time". The cycle of TOGAF methodology is shown in figure 2.

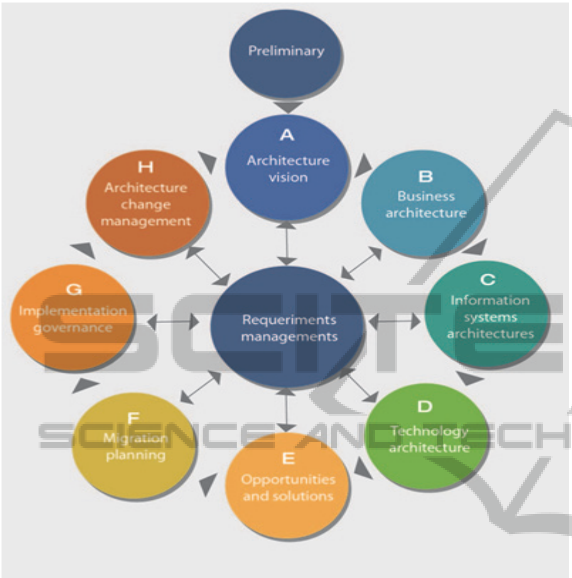

Figure 2: Enterprise architecture cycle by TOGAF.

Based on TOGAF methodology the enterprise architecture includes business and technology architecture, see figure 3.

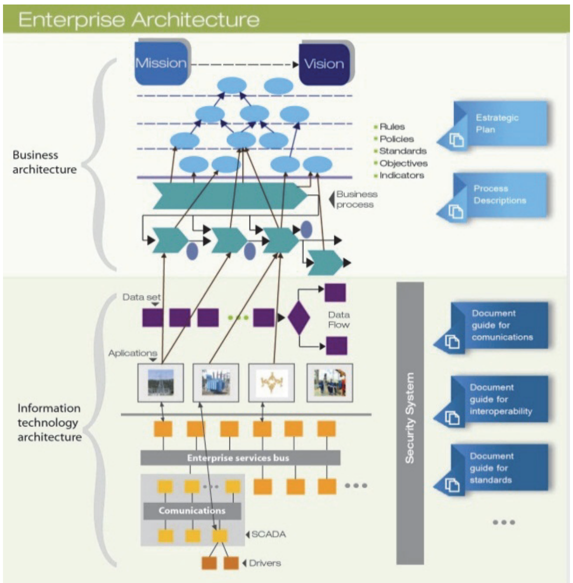

Figure 3: Enterprise architecture.

The business architecture includes the strategic plan definition and the process description. The business architecture is a part of an enterprise architecture related to corporate business, and the documents and diagrams that describe the architectural structure of that business. Architecture reveals how an organization is structured and can clearly demonstrate how elements such as capabilities, processes, organization and information fit together. The figure 4 shows the elements of a business architecture based on balanced Scorecard (BSC) and Business Processes Modelling.

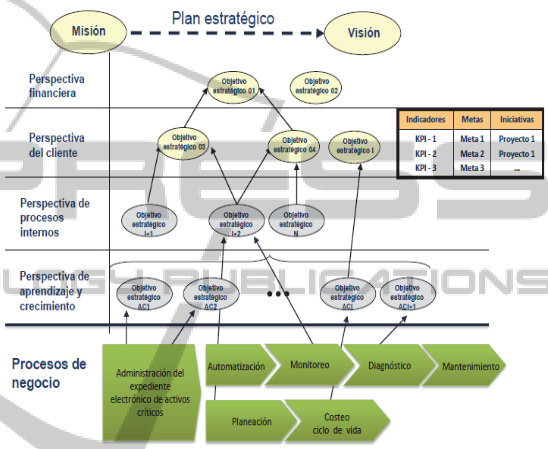

Figure 4: Business architecture.

The technology architecture includes the definition of the data set and data flow; the information systems applications management, the communication definition, the enterprise bus, the drivers, the security system and so on. The main component of the technology architecture is the enterprise service bus (ESB). The figure 5, shows an ESB based on IEC TC57 interface reference model .

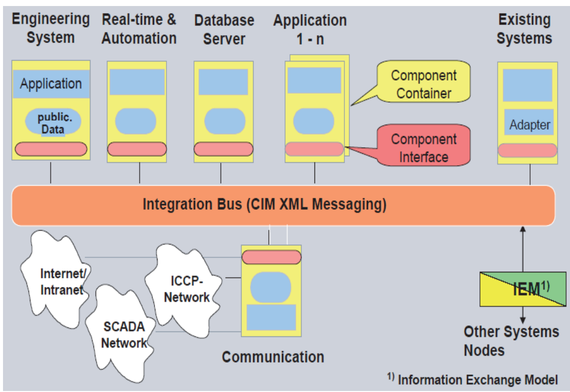

Figure 5: Enterprise service bus.

This ESB allows the interoperability of the systems. Interoperability is 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.

The Common Information Model (CIM), established in IEC 61968 and IEC 61970 is a proposal of a generic model, open and standard for ESB based in UML (Unified Modeling Language). In such a model real world elements are represented as well as their relationships, with the purpose of creating an information system which can be used among different applications for data management and interchange.

4 ENTERPRISE ARCHITECTURE FOR SMART GRID

Competitive markets for electricity have changed the organizational structures of electricity utilities as well as the operation of power systems. Interoperability between different processes requires adequate information to be brought to operators in a timely manner (Ipakchi, 2007). All these requirements brought about by electric market restructuring together with unanticipated events that may occur indicate that the communication and information systems are becoming critically important for reliable and economic operation (Miller, 2014). A need exists for a better design of the communication and information architecture accommodating large information flow to facilitate smoother control and efficient decision making (Ipakchi, 2007). The main processes of an Electric Power Utility (EPU) are shown in the figure 6.

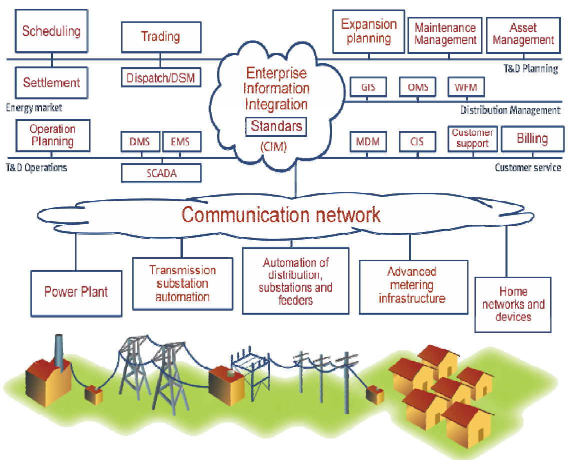

Figure 6: Main processes of EPU.

The Smart Grid concept means the total automation for all processes of the EPU. A Smart Grid is an interoperable system, it means that the Smart Grid architecture will be a composition of many system architectures and subsystem, thus will allow the maximum flexibility during the implementation, but at the same time, it will demand a high capacity of integration of the new systems with legacy systems.

For implement a Smart Grid in an EPU is necessary to define enterprise architecture. The enterprise architecture to meet Smart Grid requirements for management systems for EPU in México is presented in the figure 7.

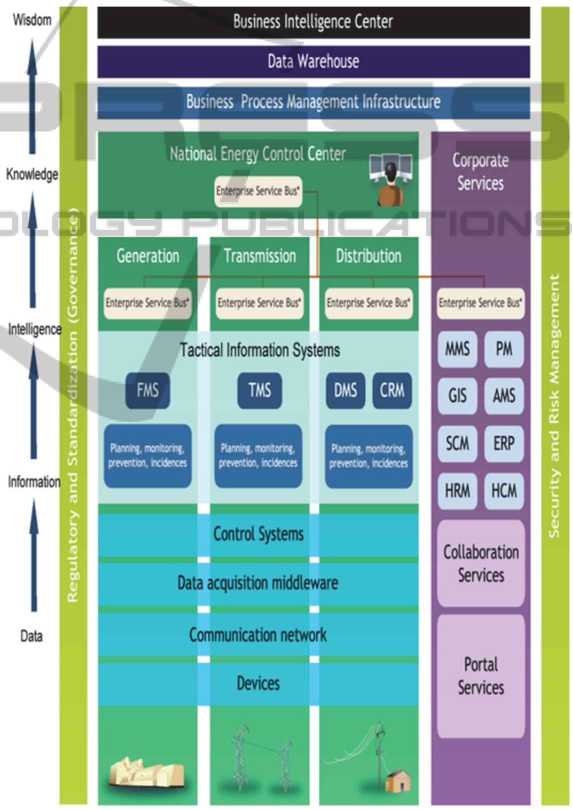

Figure 7: Enterprise architecture for EPU.

The proposed architecture adopts suitable computing and communication techniques to take into account the requirements of real-time data, security, availability, scalability and appropriate quality of service. The architecture considers the adoption of standards such as IEC 61968 and IEC 61970, which define the common information model (CIM), the IEC 61850 for substation automation, IEC 62351 for security information, COBIT and ITIL for IT governance.

The architecture shows layers of abstraction the main process: generation, transmission, distribution and energy control and includes automation and control systems at all levels, from substation control system to corporative intelligent centre, include operating centre and energy trading system.

The enterprise architecture is divided in five sections: operational systems, tactical information systems, corporative systems, business systems and standards.

4.1 Operational Systems

This level de information includes the devices, the communication network, the data acquisition middleware and the control systems. The optimal architecture must promote the unique sources of information and automatic data acquisition from its own power generation equipment, transmission and distribution systems that minimizes human intervention and allow different levels of consolidation in the corporate hierarchy, for this reason the architecture should be based on instruments that monitor and help to control major business assets such as generating plants, transmission, distribution and control systems of energy.

4.2 Tactical Information Systems

This level de information includes the automation of the main processes of an EPU.

FMS (Power Plant Fleet Management System)**:** In general, these information systems help to plan and monitor the performance of a complete system of power plants and help to prevent problems and resolve incidences. It's very difficult to have a single software infrastructure to supervise and control a large group of power plants, so we found normal to have several information systems that deals with specific needs and as a whole they represent the fleet management system. This kind of information systems sends information to strategic systems.

TMS (Transmission Management System)**:** There are several subsystems that help to manage the transmission assets in an efficient way and holistic monitoring of the complex transmission network. These information systems should perform intelligent and reliable security analysis for developing effective strategies to avert, mitigate and cope with system emergencies.

DMS (Distribution Management System)**:** Perhaps is the most complex area in terms of automating the processes. So normally there are a large number of information subsystems dealing with aspects like improve the reliability of electric service delivery to homes, businesses and industrial customers efficiently, reducing outage times, planning, resolve incidences and perform analysis for better distribution.

CRM (Customer Relationship Management System)**:** is a software infrastructure that helps to manage the customer's information not only for sales but for marketing, technical support and use patterns.

4.3 Corporate Systems

There are services that are not exclusive to the processes of generation, transmission, distribution and control center, but are common to all of them such as:

MMS: Management system for maintenance, including integral and condition-based maintenance.

ERP: Enterprise Resource Planning.

HCM: Human Capital Management. In this category are included the systems that support the formation and evolution of human capital, talent, training, skills, etc.

HRM: Human Resource Management, management of labour relations, recruitment and payroll.

PM: Project Management, technological and procedural infrastructure for project management.

SCM: Supply Chain Management. The supply chain can be supported by information systems used to coordinate the various activities involved in the interaction of business processes going from suppliers to consumers.

AMS: Assets Management. The assets of the company should be managed by information systems that not only keep a record of them, but to manage their entire life cycle.

GIS: Geographic Information System for all the enterprise including cross-cutting process.

Collaboration services: Hardware and software infrastructure to provide basic and advanced collaboration at workplaces like email, chat, videoconference, repositories, team software, etc.

Portal Services (SOA): Web software infrastructure that provides interaction with relevant information assets (for example, information/content, applications and business processes), knowledge assets and human assets and seeks to integrate and aggregate information from multiple cross-enterprise applications.

Business Process Management: The systems included in this category are the set of tools, technologies, techniques and methods for the identification, modelling, analysis, execution, control and improvement automated business processes.

Enterprise Service Bus: To complement the interoperability of information systems at the tactical level a platform of Enterprise Service Bus must be adopted, to share information between the processes of transmission, distribution, generation and national control center. An ESB is an infrastructure normally based on SOA whose purpose is to provide interoperability (connectivity, data mapping and routing) combined with some additional services such as security and monitoring.

4.4 Business Systems

Information systems in this section are those that allow to identify, retrieve, and analyze large volumes of information and provide assessments and historical, current and predictive studies as the main support for strategic decision making through a formal and disciplined process of exploitation of information to monitor the company's strategies and generate new knowledge. Business intelligence is a matter not only of technology, it is necessary that the company deploys a business intelligence strategy that is executed by the BICs and this requires an infrastructure of software and hardware as well as organization and models.

4.5 Standards

The standards and best practice for development and operation of the systems.

Regulation and Standardization: There should be a governing model that covers the requirements of the company to comply with all laws, rules and national and international regulations. There are information systems usually associated with the handling of such information.

Security and Risk Management: A comprehensive approach to security and risks management is needed in the utility; today we have found security issues practically in every component in the architecture. Normally there is an infrastructure that facilitates the management and verification of these aspects and the strengthening of vulnerabilities. The security strategy should include policies, procedures and adherence to international standards and to keep up to date on issues in areas where there is still no definition.

Architecture Governance: The architecture of information systems is important but more important to have the governance necessary to allow the architecture is feasible and successful, that is, having the definition of responsibilities, principles, policies and procedures establish a process cycle life of the architecture. TOGAF (The Open Group Architecture Framework) should be considered to define this model.

5 CONCLUSIONS

The Smart Grid strategy calls for enterprise architecture. Smart Grid architecture will be a composition of many system architectures and subsystem, thus will allow the maximum flexibility during the implementation, but at the same time, it will demand a high capacity of integration of the new systems with legacy systems. The proposed architecture provides a single, consistent view of information of the main process and includes automation and control systems at all levels, from plants and substations control systems to corporative intelligent centre, including the operating centre and the energy trading system. The architecture considers the adoption of standards such as IEC 61968 and IEC 61970, which define the common information model (CIM), the IEC 61850 for substation automation, IEC 62351 for security information, COBIT and ITIL for IT governance. The enterprise architecture is capable of providing timely, secure, reliable information exchange among various processes in the system and is also scalable.

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