Role of Interoperability in the Indian Power Sector

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Abstract

Economical growth in India has led to a considerable growth in its power sector. Issues related to system expansion, restructured environment, and changing regulatory framework demand changes in planning and operating strategies and in the design of system architecture for future needs. We explore the role of interoperability in the Indian power system context. Four levels of interoperability viz., organizational interoperability, application interoperability, information interoperability and technical interoperability are discussed with the help of typical scenarios. It is observed that interoperability among various systems of the power grid is crucial for achieving the benefits of open architecture based future control centers.

1. INTRODUCTION

Due to restructuring, owing to integration of multiple utilities in power systems and due to integration of power grids for power sharing, the number and the complexity of the functions that are to be performed by power control centers have increased. In order to keep up with the evolving requirements, the notion of central supervisory control is being replaced by intelligent distributed control of the system. As pointed out by Conti [1], unidirectional centrally controlled nature of existing infrastructure can be upgraded into an interactive, electronically enhanced grid that can spot potential problems in real-time, and automatically prevent or correct any faults or disturbances. Vendor dependent non-standard legacy devices with proprietary software and proprietary communication protocols are not interoperable. To achieve high level benefits by utilizing the powerful features that modern information and communication technologies provide, power systems of today need to focus on interoperability.

This paper presents the status of interoperability at various levels of Indian power organizations. First the current architecture, known as Unified Load Dispatch and Communication (ULDC) driving the power system infrastructure, at various hierarchies is described. The barriers for interoperability in the ULDC architecture due to heterogeneous infrastructure, modifications in the Inter Control Center Protocol (ICCP) standards by various vendors, and lack of common standards are highlighted. These limitations can be addressed by using a model driven approach [2]. In this case, Common Information Model (CIM) which establishes a semantic understanding among the applications, leading to common standard for information representation and exchange is employed. This paper describes how the use of CIM decreases the need of large number of adapters which are the means of application integration, thereby facilitating scalability.

As per the interoperability framework prepared by GridWise Architecture Council [3, 4], interoperability is classified into hierarchical levels. This paper identifies application interoperability as a level between organization and information interoperability levels. Application level interoperability is analogous to business context and business procedures levels of the interoperability framework by GridWise.

2. OVERVIEW OF INTEROPERABILITY ARCHITECTURE

In this section we provide an overview of various levels of interoperability, which we discuss in the paper. Figure 1 shows the interplay between various levels of interoperability. We consider organizational, application, information and technical level interoperabilities.

Organizational interoperability is ensured by a standard inter organization protocol, which expresses the way in which organizations have to communicate and share data. Likewise, within an organization that has a host of applications, application interoperability can be achieved by enforcing an inter application protocol. At a lower level information interoperability is ensured by complying with a standard information model. Finally, technical interoperability is achieved by standard device level protocols. It must be noted that interoperability of a level can be achieved independent of other levels. Hence, in a typical system, one can choose to standardize the levels in an order based on local priorities and policies. However, to realize the maximum benefit, interoperability at all levels needs to be ensured.

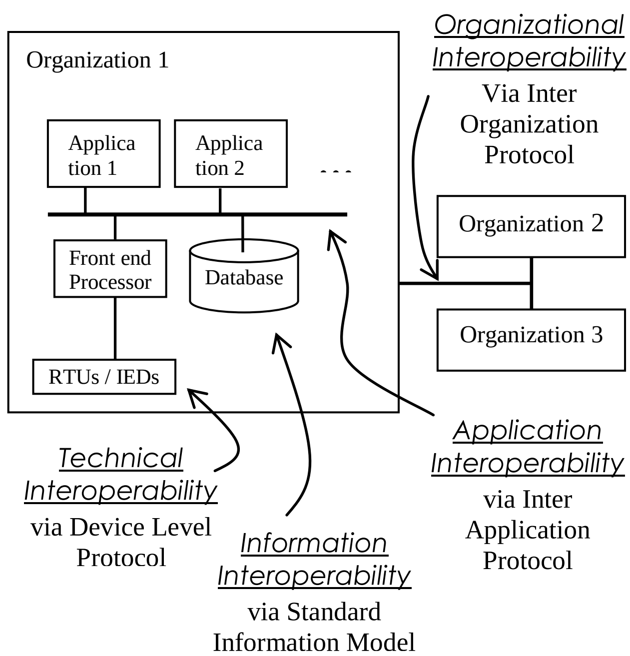

Figure 1: Interoperability Overview at different levels

3. ORGANIZATIONAL INTEROPERABILITY

Power system is characterized by vast distribution of infrastructure comprising of generation, transmission and distribution spread over a large geographical area. Though a high level centralized control center is needed for scheduling and operation of the system without interruption, certain functions can be performed by local control centers within clearly defined geographical boundaries. Thus there is a need of coordination between these control centers. However, these control centers may be heterogeneous in terms of hardware and software systems. The electricity market regulators or authorities formulate policies which define a reporting hierarchy and mandate the participating utility/organization to coordinate for operating the system. In order to facilitate coordination between control centers, interoperability is needed. This interoperability when viewed at the level of control center is studied under category of organizational interoperability.

3.1. Case study: The ULDC scheme

In India, the Unified Load despatch and Communication (ULDC) scheme is used as a structure for achieving organizational coordination. The ULDC scheme, its objectives, hardware and software architecture, and the benefits of the unified approach are defined in [5].

3.1.1. Motivation:

In India, the natural resources needed for power generation, and the load centers unequally distributed across the regions. Eastern and North-Eastern Regions are the power surplus regions and Northern Western and Sothern Region are power deficient regions. It is advantageous to shift the focus of planning the generation and the transmission system in the country from the orientation of regional self-sufficiency to the concept of optimal utilization of resources on an all India basis [6]. This resulted in need to interconnect the regional grids to facilitate inter regional exchange of power. Such interconnection mandates use of compatible software, hardware and communication protocols. But, various utilities all over the regions are using vendor specific hardware with proprietary software and protocols. Seamless data exchange between various utilities is difficult, resulting in inefficient operation of the grid.

3.1.2. Inception:

A major effort towards a unified scheme of operation and control for the Regional Load Despatch Centers and State Load Despatch Centers was made way back in early 1990's. The Unified Load Despatch and Communication (ULDC) project, also referred to as SC & C (System Coordination and Control), has been conceived to monitor, operate and control the regional power grid in a unified and coordinated manner. Monitoring of the grid system based on real-time data is vital for optimal system operation and also to minimize system tripping and blackouts. Besides, the delivery of scheduled power from Central Sector and jointly owned power plants to the beneficiary states requires a hierarchical network of load despatch centers along with adequate telecommunication facilities.

3.1.3. The operation and control hierarchy:

The control of the grid is planned to be done at three levels of hierarchy namely (1) National Load Despatch Center (NLDC) (2) Regional Load Despatch Center (RLDC) and (3) State Load Despatch Center (SLDC). Each level in the hierarchy has definite roles and responsibilities. At present, the NLDC in India is not fully operational and hence the RLDC's co-ordinate among them in the matter of inter-regional power flows. The RLDCs also have to schedule the centrally owned interstate generation stations (ISGS) and operate the inter-state grid. The scheduling and operation of state owned generation and power transmission within the state is carried out by the SLDC. The Area Load Despatch Centers (ALDCs) in turn form a lower level and are the local control centers which operate the power network of a part of a state.

The Remote Terminal Unit (RTU) is the source of information collection for the purpose of control and operation of the grid. Every RTU has a predefined Master Control Center (CC) and it has to report its data to the CC.

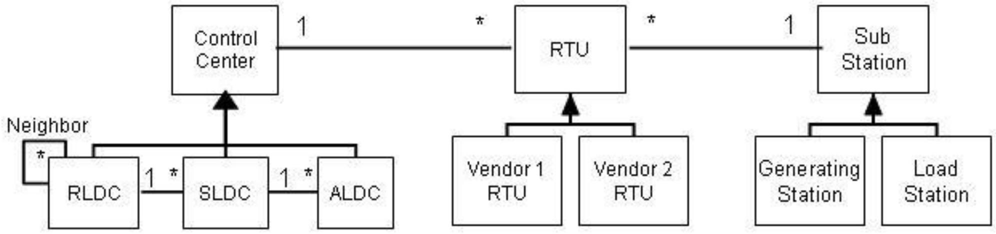

Figure 2: A model of Unified Load despatch and Communication (ULDC) Architecture in India

An RTU may be connected to an ALDC or SLDC or RLDC depending on whose data that RTU is reporting.

For example, all RTUs connected to ISGS (Inter State Generation Stations, owned by Central Government) report directly to RLDC, whereas, RTUs connected to state owned generations are connected to the corresponding SLDC. However, irrespective of the master CC, all RTUs ultimately report to the RLDC, through flow of the aggregated data between the control centers.

3.2. Scope of organizational interoperability

As a result of the ULDC scheme, a high level hierarchical organization structure is defined. This makes it easier to identify the scope of organization interoperability by considering compatibility of the equipment, standardization of hardware and software. It can be noted that information from lower level control centers to higher level control center in form of aggregation. A similar approach can be employed for exchange of control information and queries. To summarize, the information flow over the links in Figure 2 contribute to organizational interoperability.

4. APPLICATION INTEROPERABILITY

Modern control centers are equipped with a host of different applications, interacting with each other and essentially operating on the same data. Example, Most of these applications like Supervisory Control and Data Acquisition (SCADA), Energy Management System (EMS), and Business Management System (BMS) are instantiated on different servers over a Wide Area Network which may have totally different configurations and the applications themselves might be created by different vendors in different languages on different platforms. In other words, most modern power systems consist of geographically distributed assets. Even the data sources differ in terms of data semantics and granularity. It is important that in such a scenario the applications are able to communicate with each other in a standard, seamless and platform independent way.

4.1. Case study: Analytics for a large distribution utility

A distribution utility typically has a well developed SCADA system to control and operate the distribution network. However, it is observed that these operations are mainly centered on the real time data, whereas, the historical data is mainly used for basic reporting purposes.

A set of data mining applications can be developed, for extracting valuable insights about the distribution network operation from the huge database. Various other business scenarios, where such advanced business analytics applications can add value are identified as asset lifecycle management, preventive maintenance, efficient grid operation, enhanced grid observability, decision support, etc. These applications can be independently developed and provided by any third party vendors.

As shown in Figure 3, say one such application “Intelligent alarm processor” has to be deployed over an existing SCADA/EMS system. This application monitors the events occurring in the system and based on the certain events it automatically invokes corresponding services which mine the database and provide reports in real-time to support the system operator in making decisions. Such an application involves data exchange between database and other services. This creates the interoperability problems. The links in Figure 3 indentify the scope of application interoperability.

4.2. Scope of application interoperability

In order to make such a system viable the services and applications will have to agree on information exchange standards. Such an interoperability based solution will make it possible to benefit from multi-vendor implementation of services. Once application interoperability is achieved, service orientated architecture (SOA) complemented with Event Driven Architecture (EDA) can be used as an option to scale up and integrate the applications and automate the processes [7].

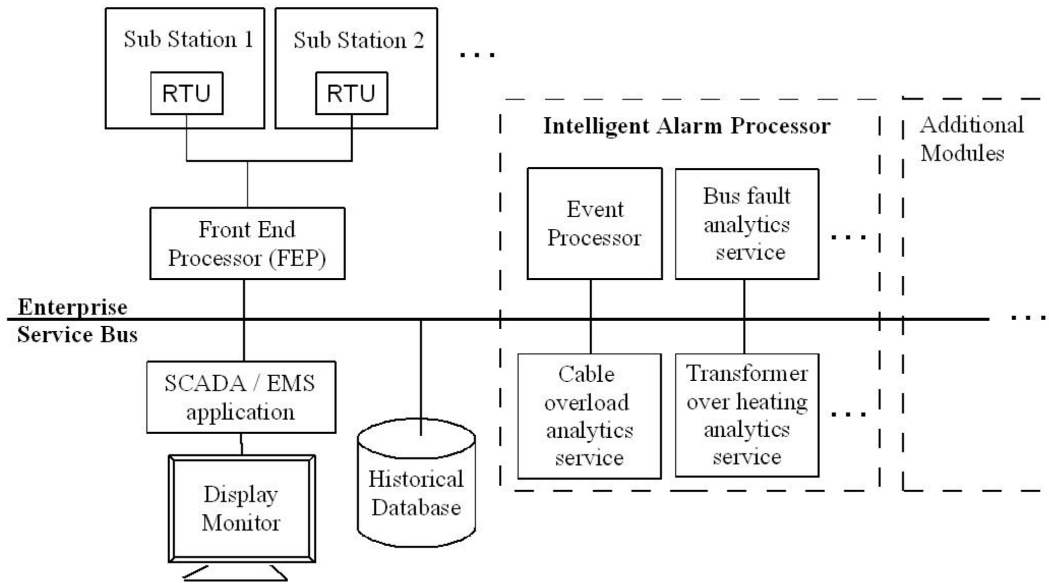

Figure 3 : Data analytics service for a large distribution utility

5. INFORMATIONAL INTEROPERABILITY

It is Interoperability by virtue of information models and protocols. The data to be processed or transferred should be stored in a well defined variable naming scheme which is known as information model. Information traveling from source over many devices to a faraway application may be mapped multiple times due to different systems, organizations, people, programming languages and communication protocols involved. This mapping creates interoperability problems. [8].

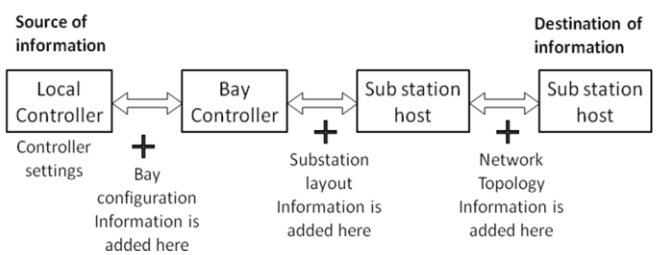

Figure 4: Multiple tagging of Information

5.1. Case study: A problem in hierarchical tagging

Consider a power system where the information from the field has to be collected and transmitted to the control center. The control center receives information from many such sources. The information collected by the source is first stored locally in the memory of the device and its address is identified a certain variable, this process is called tagging the information. Eventually when this information is passed on to other devices in the hierarchy there it will be tagged again. Moreover, this tag will also have to include the locational specification of the information to uniquely identify it as there will be multiple such data sources at this level. Thus, the information being transmitted is tagged multiple times and creates interoperability problems if the intermediate units are to be supplied by different vendors. This is depicted in Figure 4. Because of incompatible tagging schemes, one of the devices in the path cannot be replaced with that of a different vendor, although the functionality may be exactly same. This prohibits plug-and-play feature.

5.2. Case study: Interoperability between two control centers

In the practical Indian power system hierarchy the Maharashtra State Load Despatch Center (MHSLDC) falls under the domain Western Regional Load Despatch Center (WRLDC). Control centers at MH-SLDC and WRLDC have hardware and software systems from different vendors which use different information models. But their control centers have to inter operate and exchange data over the Inter Control Center Communication Protocol (ICCP) link. For making sense of the data transferred by ICCP link, we have to define the "Interoperability Table" (IOT) and Bilateral Table (BLT). IOT defines the ICCP link parameters. BLT defines the mapping of variable names between the two vendor implementations. This exercise (of defining IOT and BLT) in this case has to be performed by mutual co-operation of the two vendors, which is not easy to achieve and also a costly option for the system beneficiary.

This is typical current scenario existing in India and is depicted in Figure 5.

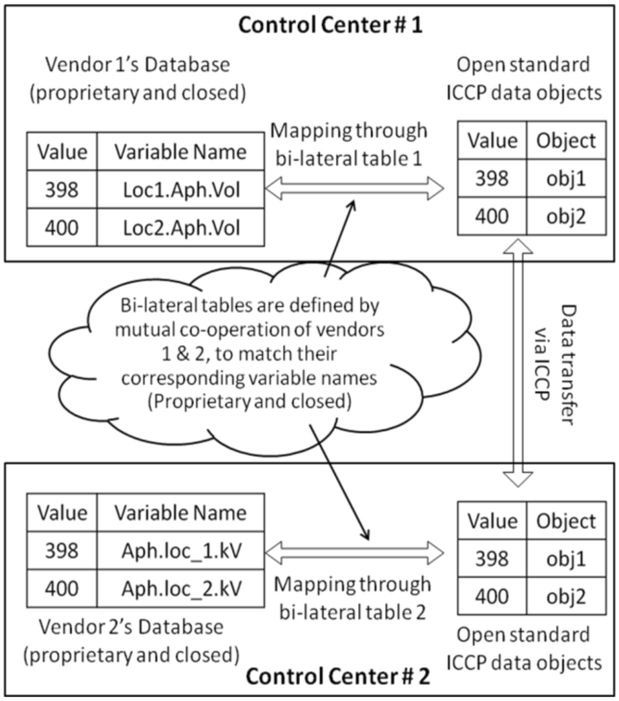

Figure 5: Typical Inter control center data transfer

5.3. Scope for information interoperability

Situations such as above can be avoided by defining a standard information model which all the vendors comply. The information interoperability can be achieved by following steps.

a) **Standardization of data types** that are needed to represent all the power system data. This can be further classified as primitive data types and aggregated data types.

b) **Standardization of naming scheme** that is needed to universally identify the variable.

The Common Information Model (CIM) is one of the means to achieve the above two standardizations. CIM is an information model, for defining data exchange semantics between the applications of various power control centers. The motivation of conceiving CIM is to achieve plug-and-play capability among the applications provided by different vendors [9]. CIM standardization exercise was initiated by EPRI over a decade ago. Today although CIM has developed as an exhaustive model, efforts are still being made to extend the CIM to account for various factors like market models etc [10]. It has become a necessity that the vendors of various SCADA/EMS software must provide CIM converters or adapters to make their proprietary information model CIM compatible and hence interoperable. In Indian context specific extensions in CIM are needed to take into account the unique local features of the power sector.

6. TECHNICAL INTEROPERABILITY

It is the interoperability at the level of network connectivity. This includes the physical medium of connection for data transfer, method to transfer data between various devices and networks establishing a syntactic understanding of the data. Usually this connectivity is achieved by dedicated hard wired communication networks, which operate with a standard protocol to drive the data transfer. However, it is envisioned that in future a more interoperable and reliable mode of network connectivity would be to use IP enabled Intelligent Electronic Device (IEDs) which have unique identification and hence can use a public network (World Wide Web) for connectivity [11]. This results in elimination of hard wired point to point connectivity and achieves universal connectivity.

In Indian power system, typically at physical level, fiber optic cables are used for inter control center communication, whereas microwave and Power Line Carrier Communication (PLCC) technologies are used for collection and transfer of data from substation RTU's to the nearest Control Center. The limitation of the micro wave and PLCC is the lower baud rate of data transfer. Above the physical medium the data transfer is achieved by the ICCP protocol [12] which is based on the 7-layer OSI communication stack. In the Indian context some efforts based on IPv6 are underway for interconnecting various networks following different proprietary SCADA protocols.

7. CONCLUSION

The role of interoperability in the Indian power system context was described with the help of a few case studies. It is pointed out that interoperability occurs at various levels. Interoperability among various systems of the power grid is crucial for achieving the benefits of standardization such as application evolution, open architecture and scalability, plug and play capability of components and services, reliability and service orientation.

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References

[1] J. P. Conti, "Let the grid do the thinking", *IET Power Engineer*, April - May 2006, Vol. 20, pp. 34-37.

[2] Richard Soley, "Model Driven Architecture", *Object Management Group, White Paper. Draft 3.2,* Nov 27, 2000. ftp://ftp.omg.org/pub/docs/omg/00-11-05.pdf

[3] National e-health transition authority (NEHTA), *Towards Interoperability Framework v1.8*, Aug, 2005. www.nehta.gov.au

[4] R. Ambrosio, S. Widergren, "A Framework for Addressing Interoperability Issues", *Panel session, IEEE Power Engineering Society General Meeting*, June 24 - 27, 2007, Tampa, Florida, USA.

[5] Power Grid Corporation of Indian Limited, "Unified Load Despatch & Communications Scheme", *Nomination for CSI-TCS Best IT Usage Award, National IT Awards*, 2003

[6] R. G. Yadav, A. Roy, S. A. Khaparde, and P. Pentayya, "India's fast growing power sector," *IEEE Power & Energy Magazine*, pp. 39–48, July/August 2005.

[7] Bobby Woolf. "Event-driven architecture and service-oriented architecture". *Technical report, IBM,* August 2006. www.haifa.il.ibm.com/Workshops/oopsla2006/present/w06 eda woolf.pdf

[8] "IEC61850, IEC61400-25, and IEC 61970: Information model and information exchange for electrical power systems", *Schwarz consulting company SCC*, Germany www.scc-online.de.

[9] Jay P. Britton, and Arnold N. deVos, "CIM-Based Standards and CIM Evolution", IEEE Trans on Power Systems, Vol. 20, no. 2, May 2005, pp -758 – 764.

[10] Enamul Haq, "CIM-Based Network Models in a Multi-Vendor Environment at CAISO", *Panel session, IEEE Power Engineering Society General Meeting*, June 24 - 27, 2007, Tampa, Florida, USA.

[11] Jeffrey D.Taft, "Blueprint for the intelligent powergrid in the electric utility of the future, Executive overview", *IBM application innovation services*, January 28, 2006.

[12] T.Saxton, D.Ambrose,and F. Kendall, KEMA-ECC, "ICCP User Guide Final Draft", *Prepared for Electric Power Research Institute,* October 8, 1996.

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