Implementing the Smart Grid: Enterprise Information Integration

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ABSTRACT

This paper presents some of the merging Smart Grid applications and discusses information systems requirements for a broad-base implementation of the Smart Grid applications. It provides representative examples, discusses existing challenges, and presents considerations for enterprise level implementation and integration of information systems in support of Smart Grid initiatives.

1. DRIVING FACTORS FOR SMART GRID

Some believe that the electric power system is in a process of a profound change. This change is driven by the convergence of information and power delivery technologies, and by the need for energy conservation and concerns regarding climate change. The changes are particularly significant for the electric distribution grid, where "blind" and manual operations, and electromechanical components of the previous century are being transformed into a "Smart Grid" by digital instruments, two-way communications, and automation.

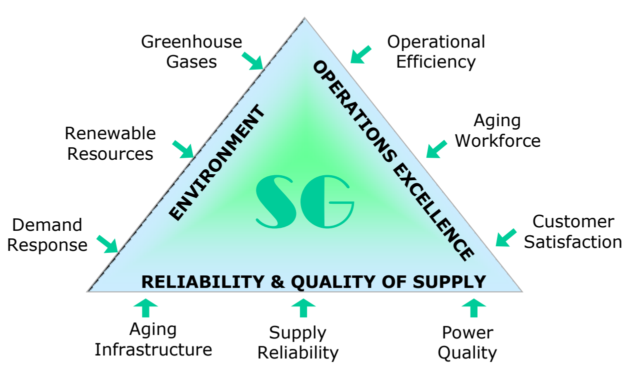

Figure 1 Driving Factors for Smart Grid

The key business drivers for the Smart Grid include:

Reliability and Quality of Supply: Our society is critically dependent on a reliable supply of electric power. The ageing infrastructure of our transmission and distribution networks threatens the security, reliability and quality of supply. Significant improvements in the reliability of power supply can be achieved through improved monitoring, automation and information management.

The Environment: Environmental issues have moved to the forefront of the utility business with concerns regarding the greenhouse gases and its impact on climate change. Many envision greater penetration of renewable resources closer to end-use consumption, and greater reliance on demand-side management and micro-grids.

Operational Excellence: Faced with the need to further improve operational efficiencies, utilities must deal with challenges associated with an aging workforce, and expectations for flexibility and improved services by regulators, customer and the market place. Utilities realize that they must shift their traditional business practices from a dependence on incumbent-based knowledge to systems-based knowledge through information management and automation.

2. THE BUILDING BLOCKS OF SMART GRID – THE SG ENABLING STACK

A "Smart Grid" vision is achieved by bringing together enabling technologies, changes business processes, and a holistic view towards the end-to-end requirements of the grid operation. We call this the Smart-Grid Enabling Stack.

Customers, consumer-side capabilities and distributed generation technologies from the base of the stack. These includes demand side automation, in-home networks and energy management systems, as well as distributed generation technologies, e.g., solar photovoltaics, plug-in vehicles, and other storage devices. The base is supported by smart meters, and intelligent monitoring, switching and control devices, as well as distribution automation technologies as an integral part of the power distribution grid. These devices, meters and controls are inter-connected through a utility-wide, and two-way data communications networks connecting customers, distributed resources and field devices with the enterprise systems and applications. This enables a broad-based demand response and distributed resource management, and it supports a self-healing grid operation.

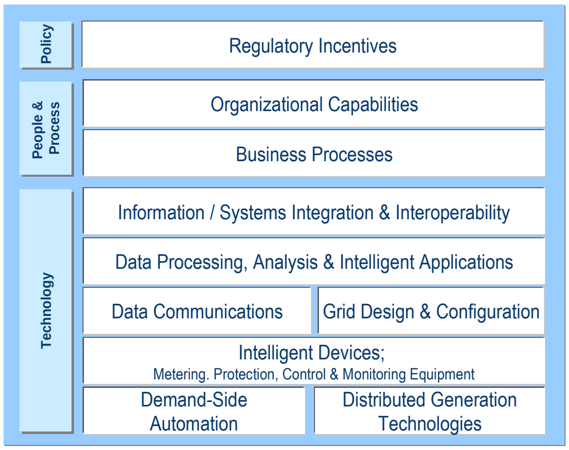

Figure 2. The Smart Grid Enabling Stack

Enhancements to distribution grid design and configuration may also be required to fully support the ever expanding penetration of distributed resources and accommodate grid automation.

Supporting these base layers is a myriad of information processing, analysis and software applications to provide the necessary intelligence and to support of various utility and customer facing operations of the Smart Grid (SG). A critical element of the SG Stack is information and systems integration to enable coordinated decision making and operations, and to enhance the overall operational efficiency and system reliability.

These technology layers need to be supported by organizational, people and process capabilities. The current utility operational processes were designed decades ago when we had limited available information and automation, and significantly relied on manual inspections and operations.

Finally, due to the regulated nature of the power industry in North America, regulatory policies and incentives are critical to major initiatives in this area. Market forces and shareholder sentiments also play an increasingly important part in grid modernization and Smart Grid initiatives.

The following sections will elaborate on the systems integration and interoperability issues layer of the Smart Grid Stack.

3. SYSTEMS INTEROPERABILITY

Utilities have implemented various pilot projects and limited scope deployments of Smart Grid applications with a minimum impact on existing operations and systems. However, a large scale Smart Grid initiative will have an impact on many utility systems and processes spanning over customer services, system operations, planning, engineering and field operations, and even power supply functional unit of a utility business.

Systems interoperability, information management and data integration are among the key requirement for achieving the benefits of Smart Grid. Automation and intelligent operations will require timely and accurate data, and the need for operational efficiencies demand coordination, orchestration and synchronization of information used by various elements of the utility operation.

Figure 3 provides a conceptual view of the typical suite of applications and system components involved in support of

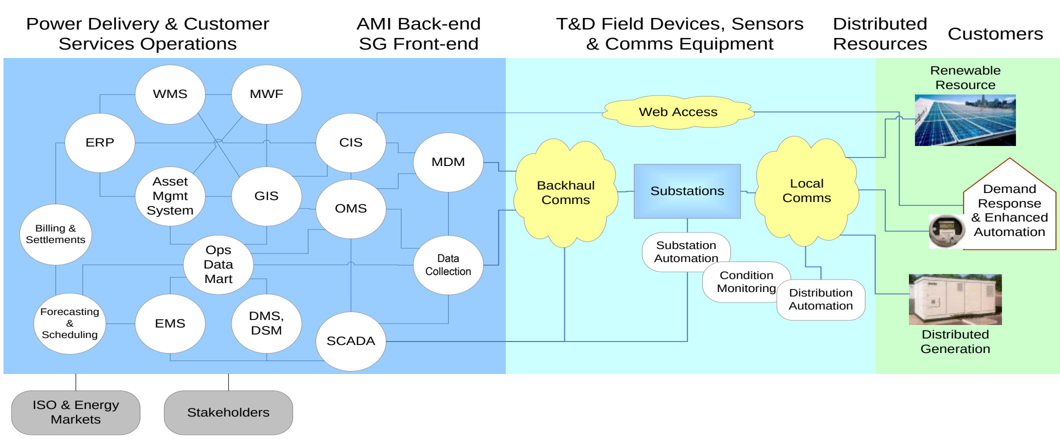

Figure 3. Systems impacted by Distribution Smart Grid

a "smart" distribution grid operation with a reasonable penetration of distributed resources, distribution automation, and Advanced Metering Infrastructure (AMI). As can be seen, in addition to advanced metering and communications infrastructure to support demand response, distributed resource management, automation functions, the deployment is also involves a number or enterprise and operational software applications and information systems.

The following subsections provide some example requirements and impact scope for large scale Smart Grid applications.

3.1. Example: Improved System Reliability

Utilities have experienced significant improvements in system reliability through deployment of a fully integrated outage management system that brings together trouble call, customer information, network connectivity, as operated filed data, and geo-spatial information. Use of last gasp data from AMI meters in real-time, and the capability to verify service delivery and restoration through the AMI communications infrastructure can significantly reduce the time for outage detection and service restoration. As shown in Figure 4, this will require integration of the Outage Management System (OMS) with a number of other applications, including AMI and supporting meter data management system (MDMS), GIS, Customer Information System (CIS), work management system, and SCADA/DMS, as well as distribution automation (DA) functions.

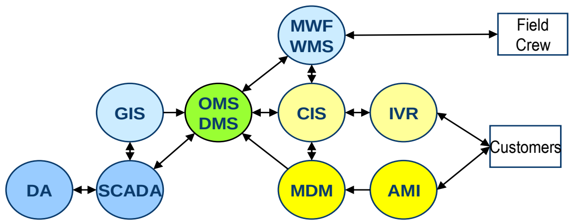

Figure 4. Interoperability requirements for Outage Management

A utility's outage management performance is typically measured by the System Average Irruption Duration Index (SAIDI) or Customer Minutes Lost (CML). Figure 5 illustrates a representative set of SAIDI values of for selected US and overseas utilities. US utilities have a benchmark of 120-160 minutes for SAIDI. European utilities typically have a higher degree of automation on their distribution network, thus the average system interruption duration, CML, in Western Europe is around 60-80 minutes. Some utilities in Asia operate based on a CML target of 5 minutes or less. These utilities have a significantly higher degree of monitoring and control capabilities on their distribution system, and have a higher degree of reliance on automation than their US counterparts. Some leading utilities in Asia, e.g., TEPCO, strive for a CML (SAIDI) of less than 5 minutes with extensive self-healing grid design and automation technologies.

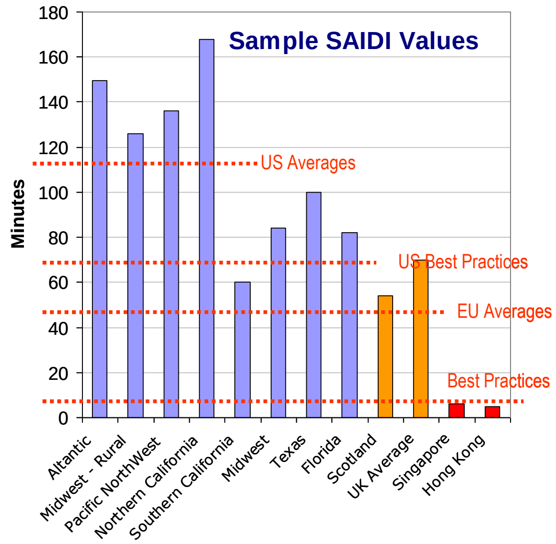

Figure 5. Representative SAIDI Values

As is illustrated above, there is significant room for improvement for the US utilities.

3.2. Example: Large Penetration of Distributed & Demand Side Resources

Today's electricity grid is designed based on a vertically integrated supply model with dispatchable centralized generation and distributed consumption with no generation resources on the distribution network. Distribution networks tend to be radial with mostly unidirectional power flows and "passive" operation. Their primary role is to deliver energy from the transmission substation down to the end-users. The design and operation of distribution grid has not changed much over the past three to four decades.

We believe that over the next decade, a proportion of the electricity generated by large conventional plants will be displaced by distributed generation; renewable energy sources; demand response; demand side management; and energy storage. Thus the Smart Grid of the future will need to accommodate more intermittent and decentralized generation, and support bi-directional power flows. In addition, distribution system may require stand-by capacity which could be called upon whenever the intermittent resources cease to generate power.

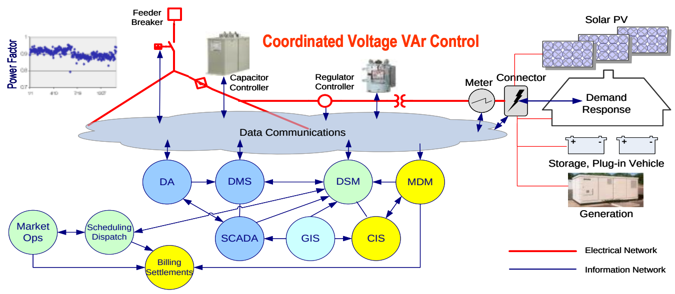

Figure 6. Systems interoperability with substantial penetration of distributed resources

The distribution grid of the future will require significantly higher degree of automation to ensure reliability and quality of the power supply. Coordinated voltage and VAr control, automated switching and relay coordination and extensive monitoring will be a necessity. The electricity grid will be interactive for both power generation sources and power consumption sinks. Enabled by in-home automation, smart metering, modern communications and the increased awareness of customers, demand side management will play a key part in establishing new services that will create value for the parties involved.

Operating a power delivery network with a substantial penetration of distributed resources will require considerable changes to the existing network operating practices. As illustrated in Figure 6, many of the information management functions involved with distribution management and automation, operations planning, scheduling and dispatch, market operations and, billing and settlements will be impacted.

The electricity distribution network needs to be supported with an information management network that may play an equally important role for delivery of electric power to end-use customers. The information network will brings together the diverse data needed to manage generating and demand resources on the distribution network while maintaining power quality and reliability.

3.3. Example: Asset Management

Another important aspect of a Smart Grid is how the transmission and distribution assets are managed and maintained to ensure a high degree of system reliability while optimizing Operations & Maintenance activities. Coordinated asset management, equipment condition monitoring, condition-based inspection and maintenance, dynamic adjustment of operating limits and equipment rating based on their condition are among the strategies that a modern grid operation needs to employ. These strategies improve O&M efficiencies, extend equipment life and improve maintenance processes. This in turn results in enhanced system capacity and improved system reliability.

These objectives require smart monitoring devices, data collection and conversion of the data to information, and taking action based on that information. A system-wide deployment of asset management strategies will require integration of data from such systems as SCADA, meter data management, GIS, Supply Chain (ERP/AM), and coordination of those data with work management, mobile workforce, as well as EMS, DMS and OMS applications.

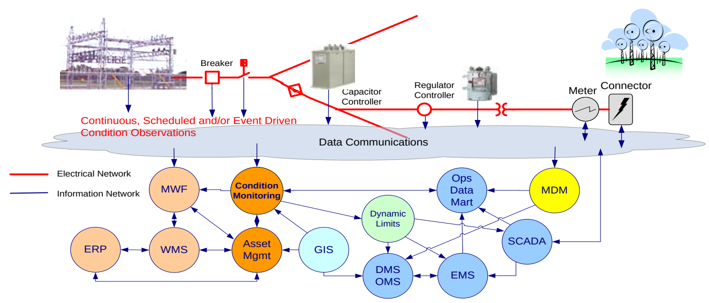

Figure 7. Systems Interoperability needs for Asset Management

4. ENTERPRISE LEVEL INTEGRATION – DATA ASSETS

Currently most utility companies have limited installed capability for interoperability across the applications associated with system planning, power delivery and customer facing operations. In most cases, this information in each organizational "silo" is not easily accessible by applications and users in other organizations. These "islands of information" corresponded to islands of autonomous business activities. The Smart Grid strategy calls for enterprise-level integration of these islands of information to improve information flow and work throughout the organization. It is important to provide a single, consistent view of information throughout the organization, making enterprise data accessible securely and in a timely fashion to authorized users across the enterprise.

There is an emerging trend to treat information as enterprise asset. These assets need to be properly managed, controlled and made available to different users and applications across the enterprise. For example, the network connectivity and spatial data in GIS are needed by many applications, e.g., Outage Management System (OMS), mobile workforce (MWM), Customer Information System (CIS) for customer mapping, systems planning and engineering in support of asset management and network analysis, and by SCADA for world-maps, etc.

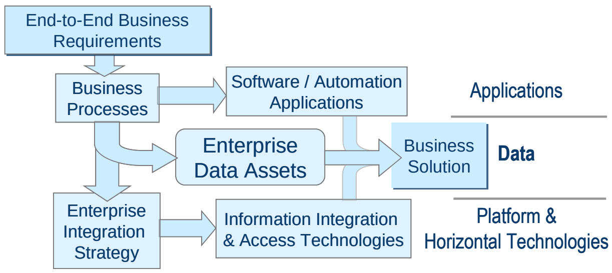

Figure 8. Key process elements for integrated Smart Grid information management

A key requirement for information integration and management across the utility operations, especially in the context of Smart Grid, is the definition of the Enterprise Data Assets. This is data that is accessed and used across the enterprise by business operations and systems. Figure 8 illustrates the key process elements in deployment of integrated Smart Grid solutions. As can be seen data management and data integration play a central role in creating an integrated business solution. The accuracy, integrity, reliability, timeliness and accessibility of these data assets are critical to the "smart grid" operation.

A simplified illustration of the data assets concept is provided in Figure 9. A key requirement for the data assets is the establishment of the System of Records (version of truth) for these assets. A formalized and comprehensive data management principles needs to be established to manage these assets.

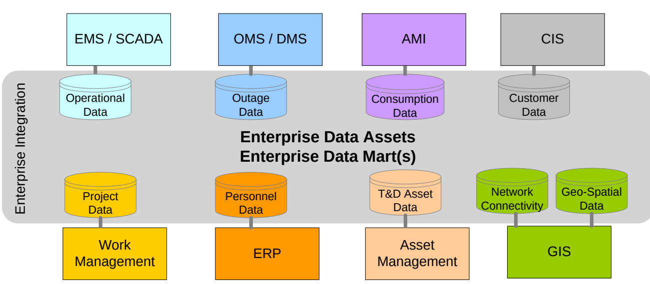

Figure 9. Key operational Data Assets

The key elements of the data management principles include:

Data Stewardship – to define the data ownership and its Chain-of-Custody;

Data Organization – to establish data modeling and definition standards, and to define the System of Records for the enterprise data assets;

Data Content Management – to establish processes and responsibilities for data update, maintenance and quality management;

Data Access – establish methods, and tools for data access including data security and availability; and

Data Presentation – including visualization and data transformation, as well as business intelligence required to covert data to useful information.

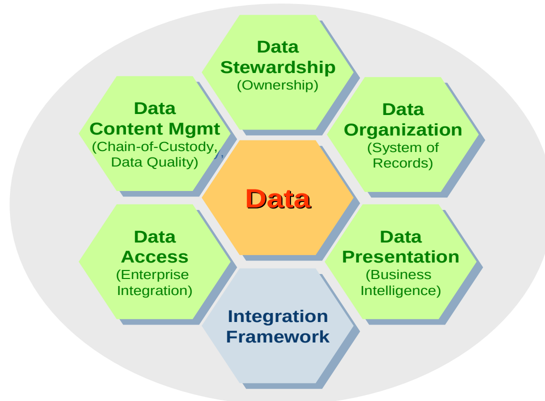

Figure 10. Enterprise Data Asset Management Principles

Traditionally, data was an embedded part of an application. For example, SCADA data was only accessible through SCADA operator consoles, reports and data export capabilities. In the case of SCADA data, many utilities have used a separate data warehouse moving the data from the SCADA system to a separate repository for access by other enterprise users. This concept can be generalized through creation of enterprise level data marts to bring together the information needed by operations across the organization. Such data marts can be physical or virtual, i.e, a separate physical database, or a federation of databases associated with different applications.

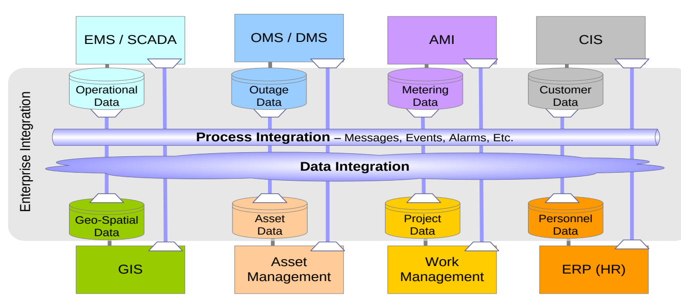

Figure 11. Enterprise Information Integration

Implementation of Smart Grid will require integration of processes and information across a multitude of systems and applications within utility system operations, planning and engineering and customer services. The technical integration activities will include integration of data and messages associated with real-time events, alarms and other notifications that require immediate attention, and integration of data associated with assets and networks, their configuration, condition, and other operational and business data that can be accessed across the enterprise on a bulk or transactional basis. Thus, on a conceptual basis, the enterprise level information integration for Smart Grid applications can be sub-divided into two general classes: 1) real-time notifications, control and process integration, and 2) bulk and transaction based data exchange amongst different applications. For example, the exchange of network connectivity models between GIS, DMS, OMS and planning applications can be considered as a bulk data transaction, where notification of an outage can be considered as a real-time event.

There are many techniques, technological solutions and vendor offerings for enterprise-level information integration, including various middleware message bus products, web services and other technologies and tools for systems integration under a service oriented architectures (SOA). A key industry challenge at this stage is the lack of broadly developed and supported reference models and standards for integration of field devices, smart meters, renewable resources with software applications integration, and applications interoperability in the distribution space.

Some of the existing industry standards efforts e.g., IEC TC57: IEC61850 for Substation Automation, IEC61968 for Distribution Management Systems – IEC61970 for Energy Management Systems and Common Information Model (CIM) provide some framework for this, but they are not fully adopted and supported across the industry. Other IEEE, ANSI and other regional and utility standards for network design, distributed generation interconnections, and operations also exist, but may present certain limitations when dealing with the broader Smart Grid requirements.

5. ROADMAP FOR SMART GRID IMPLEMENTATION

Many utilities have initiated strategic plans for modernization of their power delivery and distribution operations. This is in part influenced by the synergistic capabilities of AMI technologies, especially its ubiquitous two-way communications capabilities. Also the need for improved system reliability, enhanced operational efficiency, and support for distributed resources as well as demand-side programs are also driving the modernization needs. The roadmap to implementation should consider the following:

Strategic Planning - Smart Grid requires a coordinated phased implementation and roll-out plan spanning over several years covering design, implementation and change management.

Regulatory Strategy – Strategies for cost recovery and regulatory alignment.

Holistic Approach – Smart grid requires a holistic approach to operations and business surrounding systems planning, power delivery and customer services. It requires a transformation away from a "Silo-Based" Business.

Business Case Justification – It requires a sound business case regarding costs and benefits associated with technologies and business transformation. Leveraging project synergies is a critical factor to the business case justification.

Enablers and Foundational Capabilities - Identification and implementation of enabling and foundational capabilities, including people and process, are critical to the long-term success of these initiatives.

Interoperability Standards – Establishing enterprise level governance, adopting interoperability standards and developing an architectural framework for data, systems and technology integration is an important step in implementation of Smart Grid initiatives.

Practical, Balanced and Leveraged Solutions – The need for business continuity and that leverage existing investments demands practical solutions that augment current capabilities and interoperate with existing systems and processes.

The future models for the Smart Grids have to meet changes in technology, and accommodate public values related to the environment and commerce. Thus security, reliability, safety, environment, power quality and cost of supply will all be examined in new ways and energy efficiency in the system will play an increasing role in balancing the system. The industry has already embarked on this journey the length of which will be determined in large part by how well all the players and decision makers understand the costs and benefits of modernization.

Biography

Ali Ipakchi has over 29 years of experience in delivering system solutions and services to the electric utility industry. He has assisted utility clients with specification, design and deployment of automation and information technologies for improved grid operations. Dr. Ipakchi is an industry leader in development and promotion of Smart Grid concepts, and has helped utilities with strategic planning, cost benefit assessment and deployment road map for technologies needed for Smart Grid operations. Prior to joining KEMA, he held a senior management staff position at a leading T&D vendor responsible for key software products development and delivery. He has managed many large IT projects leading engineering and technical teams.

Dr. Ipakchi is co-holder of three US patents on power systems applications and instrument diagnostics.

He has a successful track record of helping major organizations expand business and, develop products and services with his strong technical and business management skills. He brings extensive IT systems experience for utility T&D operations including system control centers, distribution operations, customer care, market operators, trading floors, and merchant power operation centers.