The Smart Grid– Where to Start

The Five Foundational Elements of the Smart Grid

People matter, results count.

Introduction

Deploying a Smart Grid is not a project. It's not even a program. Though it might be launched as such, it quickly evolves into something far greater. It is, in fact, a transformation.

As utility companies across the world are increasingly discovering, the deployment of a Smart Grid fundamentally changes the way they generate data, present information, make decisions, execute work and relate with their customers. For this reason, it is important to ensure that the foundation of your Smart Grid is solid.

Many, if not all, of the foundational elements are already in place at most utilities. However, getting them to meet the new requirements that Smart Grid creates will present significant challenges to those responsible for deploying and operating them.

To help your company overcome these potential roadblocks, Capgemini will describe the five critical elements and associated issues that utilities will inevitably face in deploying a Smart Grid: **GIS Data and Processes, Existing WAN/LAN Networks, Energy Delivery Network Topology, Integration Architecture, and OT/IT Systems.** Based on our experience in collaborating with leading utilities on successful Smart Grid deployments around the world, this document provides our insights and recommendations for building a strong Smart Grid foundation.

Element 1: GIS Data and Processes

Why is the GIS so Important to the Smart Grid?

Remember that new Geographic Information System (GIS) you put into place a decade ago? You should consider your company lucky if the GIS was deployed with the needs of passing a robust data set to an Outage Management System (OMS) in mind. Even luckier, that GIS data has been rigorously maintained and updated over the years. And luckiest of all, that GIS adheres to an industry integration standard.

With the Smart Grid's promises of a more reliable, robust electric delivery system comes the virtual representation of that system used to make operational decisions. The source of the base data for this virtual representation is the GIS. If the GIS data is not accurate and timely, or if the information cannot be easily transferred to the other systems that require it, the decisions made based on the virtual representation are flawed from the start. Advanced Distribution Management Systems (ADMS) require an accurate model of the network to perform basic power flow calculations. In addition, due to the integration of distribution energy resource management, relay protection analysis and state estimation to name a few ADMS functions, the accuracy of information becomes paramount. This is why it is essential that the GIS has the following characteristics:

Phasing Accuracy

The phases represented in the GIS data need to correspond accurately with the phases in the actual delivery network. This is vital for the monitoring and operating of unbalanced distribution systems. In addition, new ADMS have applications such as Network Reconfiguration that will suggest new open points to optimize the distribution system by minimizing line losses.

Connectivity Accuracy

The network connectivity hierarchy from the sub-station, distribution feeder, transformer and customer meter needs to be electrically accurate for the safe and effective operation of the distribution network and to ensure optimal customer management.

Landbase Accuracy

When passed to the OMS or a Mobile Workforce Management System (MWM), the GIS landbase needs to be accurate and consistent. This is typically a challenge for companies involved in a recent merger or acquisition, requiring them to integrate GIS data from multiple legacy GIS systems with varying coordinate systems and then coordinate projections. Operationally, vehicle routing decisions are based on this information. From a planning and engineering standpoint, land use and the placement of devices, lot lines and other facilities rely on an accurate GIS landbase.

Spatial Positioning Accuracy

Wasted time and frustration of field personnel can be avoided if the device they are sent to repair is (or in some cases was) physically at the coordinates the virtual system tells them – or at least within sight of the location. This is a significant issue with rear-lot construction and during major restoration events when repairs and changes to the system are not reported timely or accurately.

Ability to Provide As-Designed Energy Delivery Network Model

The GIS must be able to efficiently and effectively export the required data to the systems that need it, preferably in a format that is easily imported by those receiving systems. This is as much a procedural challenge as a technical one, requiring a quality assurance and quality control process to ensure the exported GIS data will render without excessive exceptions into the new as-operated network model.

Element 2: Existing WAN/LAN Networks

Existing WAN/LAN Networks

It is critical—at the early design stages of the Smart Grid—to perform a thorough analysis of your existing WAN/LAN infrastructure configuration in relation to the physical locations of the Smart Grid systems hardware and backhaul connectivity locations. It may be necessary to rebuild or replace a portion of this infrastructure, which is neither quick nor inexpensive. Some of the key areas to analyze are as follows.

Security

Data network security for the Smart Grid is paramount. In the early design stages of the Smart Grid the issue is not necessarily what security capability is needed, but what capability can be supported by the existing network infrastructure that needs to be known. Once it is known, a valid gap can be determined and the economic impact of closing that gap calculated. Having half of the equation accurately determined and documented can save time and money through the reconfiguration of existing infrastructure. The capability of your existing network to support Virtual LANs (VLANs) is a critical component to implementing a secure Smart Grid.

Bandwidth

Do you know how much bandwidth remains on your existing network? A Smart Grid implementation will regularly require massive, multiple-terabyte data transfers between strategic points of the WAN. If you don't want these transfers to slow the performance of your network to a crawl, you need to consider a few things: How much bandwidth do you really have available for the data packet types you will be moving around and can your existing network manage or prioritize the movement of those data packets? If you have only a few Mbps remaining and cannot implement Quality of Service (QoS) on the existing WAN, your Smart Grid budget just got bigger.

Robustness

Simply put, a robust network is difficult to break. This is the result of many factors including hardware, software, infrastructure management, transport medium, and the physical path that medium takes. Redundancy and geographic separation are both key. The use of SONET or other fast-failover fiber technologies is typical. You cannot hang any part of the Smart Grid core on a long radial branch and if you don't use High Availability/Disaster Recovery architecture for Smart Grid systems and applications, you are placing your operation at significant risk.

Resiliency

Even the most robust network can fail, and every second of recovery time exacts a heavy toll on productivity. That's why it is critical to ensure the resiliency of your network by selecting and configuring technologies and hardware from the back-office systems, through the WAN core to the end-point devices in the field (meters, capacitor controls, etc.). It does you little good to have a field RF Mesh network that can rebuild itself around a failure in seconds or minutes if the WAN takes eight hours to rebuild, or visa versa. Resiliency is a holistic measure and needs to be determined and designed that way.

Required Connectivity

Do you need to replace the entire WAN to deploy a Smart Grid? The classic answer is: maybe. If your WAN is configured in a ring topography, and your Smart Grid systems and feed-in/out points are distributed around that ring, you need to ensure the robustness and resiliency are adequate between these critical points of the WAN.

Time Synchronization and Propagation

Time and the synchronization of it across the Smart Grid and the connected systems, applications and devices are critical. This synchronization takes place via the data network. Your WAN/LAN/ Field network must support the propagation of a common time reference, typically from a GPS synchronized source, down to the millisecond for some field devices such as fault indicators. Do not be surprised if your legacy systems (mainframe) cannot make use of this signal. And Daylight Savings Time (DST) will become a thorn in your side. Operating all Smart Grid systems and applications on Coordinated Universal Time (UTC) is the easiest method to avoid DST issues.

Element 3: Energy Delivery Network Topology

Because the Energy Delivery Network (EDN) is at the core of utility distribution operations, it is the most pervasive – and the most exposed – system that utilities own. The ability to effectively reconfigure the EDN to reduce the time customers experience power outages depends on the topology of that network. How close is your grid to an actual grid of intersecting or crossing circuits of diverse sources? If you are in the U.S. and not in an urban center, the odds are pretty slim the EDN around you is anywhere close to a grid in its topology. Much of the EDN in the U.S. has a radial star topology and circuits from different substation sources rarely cross paths. To realize a major consumer benefit of the Smart Grid, fewer or shorter outages, this needs to change.

Design Practices

Do you design your circuits to achieve a predetermined Customer Average Interruption Duration Index (CAIDI)? Do you consider the proliferation of residential distributed energy resources (DERs) such as photovoltaic (PV) or plug-in hybrid electric vehicles (PHEVs) in your designs? Do you consider nearly 100-percent reverse power flow a normal occurrence on distribution circuits? Do you require feeders to tie with other feeders from different substations? These are only a few of the design challenges your engineers need to overcome to deploy and extend the Smart Grid EDN.

Alternate Paths

Reducing CAIDI boils down to two critical variables: the number of customers out of service and the minutes they are out. The reduction of either relies on the isolation of the fewest customers and the restoration of power to the remainder. Without a diverse source grid topology, you cannot restore power to customers beyond the cause of the outage via an alternate path.

Substation Capacity

Having a grid topology does you little good if the substation transformers are at maximum capacity. Adding additional customers to a feeder powered by a transformer already operating at or over-capacity puts the highest cost device (the substation transformer) at greater risk of degradation and failure. Do you know the real-time loading of your substation transformers? Including the VAR loading? Could the addition of utility owned storage or distributed generation provide the needed capacity without changing the transformer? These factors need to be carefully understood before feeders and substations begin relying on each other to mitigate outages and to provide load relief.

Circuit Capacity

The move to a true grid topology EDN requires the removal of circuit capacity and voltage level constraints to normalize power flow paths and provide the required operational flexibility. Standardizing on as few voltages and conductor sizes as possible is necessary to achieve this.

New Smart Grid Infrastructure Impacts

New Smart Grid infrastructure such as distribution energy resources need to be considered carefully in your planning, design and operation analysis.

EDN will require bi-directional voltage regulators to accommodate imbedded renewable generation that not only supply the expected feeder load but can produce power back to the transmission system.

Physical Field Asset Capacity

Poles, cross arms, brackets, insulators, and down guys all have physical constraints. Do not underestimate the impact that the new Smart Grid EDN will have on these. New, larger conductor sizes may require the wholesale replacement of cross arms, insulators, brackets, and down guys – possibly even poles – due to the additional weight of the conductor. And if you need to increase voltage levels, the same may be required to ensure adequate conductor height and spacing.

Construction Standards

The Smart Grid brings with it new field hardware from RF Mesh repeaters to three-phase, peer-to-peer communicating, automatic load break switches. How are these devices installed in the field? Where do the communications devices attach to the pole? How are they grounded? Are the bypasses fused or solid? The list goes on and on – and needs to be completed to provide adequate construction standards for designers and construction crews.

Logistics

The addition of communications configuration and control programming, both specific to devices' physical and electrical locations, adds new installation steps to the deployment of previously "dumb" devices. Who will perform these new tasks? When will they be done? How will the configuration information be recorded, documented, and maintained? To ensure the right device is readily available whenever and wherever it's needed in the network, you must closely coordinate purchasing management, materials management and device preparation.

Element 4: Integration Architecture

If your integration architecture is built upon point-to-point interfaces, the deployment of your Smart Grid and the systems that operate it will, at the very least, be an interesting endeavor. This is not to say point-to-point interfaces are not needed. In certain circumstances, they are preferred. However, the broad spectrum of data to be collected, transformed, and managed, and the value of sharing this new information across the enterprise, makes the use of point-to point-integration well, nearly pointless.

Security

Security must be intrinsic to your integration architecture, as well as your network infrastructure and applications. Integration security deals with the separation and isolation of data elements in systems, data tables, message schemas, and ESB transport layers. It also encompasses the control of the meta-data repository associated with the Common Information Model (CIM) and access to that control. The ability to trace and log individual data elements as they traverse the integration layers of your Smart Grid can provide invaluable information in the unfortunate event of a security incident.

Service Oriented Architecture (SOA)

The best mature solution to supplant point-to-point integration methodologies, especially with the number of systems in a Smart Grid solution, is a Service Oriented Architecture (SOA). This allows systems to provide data to other systems that need it essentially "on-demand," enabling a one-to-many integration with a high level of standardization.

Enterprise Service Bus (ESB)

The large number of systems, new and legacy, involved in deploying a Smart Grid solution makes the most efficient method for integration the implementation of a services-based message bus. Commonly called an Enterprise Service Bus (ESB) or just "The Bus," it provides flow-related concepts such as transformation and routing to a SOA... An ESB also provides an abstraction for endpoints. This promotes flexibility in the transport layer and enables loose coupling and easy connection between services. So what does all of that mean? The systems of a Smart Grid can be integrated via SOA without an ESB. However, an ESB makes a SOA more robust and flexible. Think plug and play at the system level.

Common Information Model (CIM)

IEC 61868 and IEC 61870—collectively referred to as "the CIM," enable interoperability between systems at the data level. So what does that do for you? It minimizes the need for data transformation between systems—i.e. the minimum data definition and attributes are the same in all CIM compliant systems for the same data element called "CUSTOMER." When combined with an ESB, it becomes the standard data set for your enterprise. Powerful. You need this to realize the full benefits of your Smart Grid implementation.

Business Process Monitoring or Management (BPM)

How well do you know your existing processes? Are they adequately documented? Better yet, do you know how your business processes will change during and after the implementation of a Smart Grid? The Smart Grid will transform how employees interact with each other, customers, information and the Energy Delivery Network (EDN) itself. All of this interaction enables better decisions and more effective actions. And the ESB mentioned earlier can make use of these processes to get the right information to the right personnel and systems at the right time. The ESB can also provide

Element 5: OT/IT Systems

Few Smart Grid deployments involve the replacement of all information systems in a wholesale manner. So, the odds are there will be multiple existing OT / IT systems that need to be integrated into your Smart Grid solution. Systems such as the Customer Information System, Protection & Control Management Information System, Power System Data Base, Geographic Information System, Outage Management System, Distribution Management System, Energy/Network Management Systems are examples of some of the OT/IT systems used today by most utilities.

Wherever your Smart Grid deployment starts, planning, testing and implementing the integration with these systems will be an activity of paramount importance and a key delivery point for a successful outcome.

Control Systems

Today Advanced Distribution Management Systems bring together DMS and OMS under one roof, providing economies of scale by using a single user interface. Since OMS and DMS share a distribution system model that must be maintained and kept up to date at all times, there is significant benefit to the utility if there is only one instance of the model to build and maintain. The common network operating model will be primarily built and maintained in the enterprise GIS.

To realize the full value of integration between the new control systems and the legacy systems, key information data needs to be shared amongst these systems. Typically DMS and EMS/NMS systems share information at the demarcation point. DMS and OMS systems need to share real time data to enhance the OMS predictive outage intelligence for customer restoration.

In addition, control systems have a large number of interfaces with other enterprise applications, networks and tools. Upgrading or new implementations must be very well planned and closely monitored to ensure maximum efficiency. There are different architectural models to consider for integration. Sometimes point to point integration is the most logical, for others SOA integration employing an enterprise service bus (ESB) is the most practical and flexible. Business requirements will determine what information you need to provide from different sources. Depending on the solution, the architecture can and sometimes do involve customization if different OT vendors are employed.

Protection and Control Management Information System

Some utilities have a Protection and Control Management Information System where the relay protection data is stored. Advanced Distribution Management Systems have applications that utilize this data to ensure the system is protected when re-configured. Applications such as ‘relay protection analysis’ and ‘adaptive protection’ in particular need and use this data to support reconfigurations for the day to day outage planning and for customer restoration in the real time control room environment. Creating that interface between these systems is a key undertaking to improve the manual inputting that would be needed otherwise.

Geographic Information System

A geographic information system (GIS) integrates hardware, software and data for capturing, managing, analyzing and displaying all forms of geographically referenced information. In the utility space, the GIS maps the location of all the electrical assets including the wires and switchgear. In addition the GIS provides equipment attributes such as the length of line sections and size of the conductors. The end product is the production of the distribution system in a geographical and single line display. Sometimes GIS databases do not include power system idiosyncrasies such as fields to distinguish single phase disconnect switches versus gang operated disconnect switches verses load break disconnect switches. These devices have different operating characteristics and need to be displayed with different symbology on the geographic and single line displays. In addition, their characteristics are directly tied with other advanced applications like ‘switch order management’ when the operating of devices are provided automatically to the user.

Outage Management System

The core OMS functionality is to provide a predictive outage location based on customer reported power-off calls. This auto-prediction functionality has greatly reduced work effort in outage management and crew dispatch during large outage events.

Over the years, advancements in Interactive Voice Response (IVR) for incoming and outbound customer outage communication, restoration call-backs and customer identification have greatly improved the customer satisfaction levels during outages and have become integral to OMS.

Typically OMS have some basic crew management functionality or an integrated Workforce Management (WFM) module that provides occurrence, cause, repair inputting and reporting and interfaces for time and accomplishment reporting. Through mobility advancements, much of this functionality is available on a tablet or mobile terminal device (MDT) for greater flexibility of receiving and reporting information for field crews.

More recently, interfaces built to provide AMI information and access to the AMI network are becoming increasingly popular with utilities to improve outage management processes by receiving last gasp meter information and providing the ability to “ping” a meter to confirm restoration.

For optimum outage location prediction, interface linkages between OMS and SCADA, or a DMS provides real time outage incident creation in the OMS. This provides more accurate outage information for reporting reliability indices such as SAIDI, CAIDI and SAIFI that most utility regulators require.

MDMS

The critical role of an MDM system is to very quickly process large volumes of granular interval meter data. In the past only commercial and industrial meters collected interval data but with the onset of AMI, the entire meter population is now bring back this data.

Although MDMS are core to Smart Meter solutions, they also play a significant role for ancillary Smart Grid services. Interval energy usage provides a very accurate load profile of the customer, the associated distribution transformer, the primary distribution feeder up to the sub-station.

In the past customer load profiles have been typically derived from the placement of electronic recording devices across various points on the network. The usage information from the MDMS is much more detailed to each end-point. Customer profiles become very accurate and provide an excellent source of information for the advanced applications of the ADMS in particular state estimation, load allocation and load forecasting.

CIS

The Customer Information System (CIS) includes modules for customer account management, billing and customer requests such as move-in / move-out or electrical service upgrades. Interfaces to OMS are required for customer premise information such as address and contact information as well as providing the customer meter to transformer relationship. The meter to transformer relationship is key to maintaining a correct upstream electrical connectivity model from a customer service perspective.

Data Management and Reporting

Given the reams of information that is now being collected across the grid, there is a need for next generation data management systems to harvest the full value of the information, not only for the visual crystallization of the distribution system but also for enhanced asset management of the distribution system components.

There are a number of key areas such as data warehousing, data mining, data analytics, data reporting and dash boarding in general for the production of key summary screens of the distribution system, not only for the staff operating the grid on the shop floor or in the field but also for executives, stakeholders and customers.

With large T&D systems now being operated by most utilities, grid intelligence (ability to visualize grid performance in the real time), asset intelligence (having the ability to monitor asset health for the enhanced operation of the system & to proactively reduce equipment failures & subsequently maintenance costs) and the ability to produce simplified views and reports is becoming paramount.

Legacy IT System Considerations

Legacy IT systems will be included in the overall architecture of the utility Smart Grid solution. There are many factors that will cause significant constraints around the following issues:

Few Smart Grid deployments replace all involved information systems in a wholesale manner. So, the odds are there will be at least one legacy IT system integrated into your Smart Grid solution. The prime suspect is the Customer Information System (CIS). These legacy systems typically have significant constraints around the following issues.

Security

How secure are your legacy IT systems? How many personnel have the knowledge of the systems to detect malicious code? How strict are the levels of user access, audit logging, and data validation/ integrity checking? How are legacy systems exposed to the newer integration technologies? Be aware, as legacy systems are integrated into the near-real time Smart Grid world, their security constraints need to be addressed.

Place in Lifecycle

Understand where the legacy systems involved in your Smart Grid solution are in their useful lifecycle. It may be worth the wait for an older system to be replaced before spending the time and money to integrate it. Also, systems at the newer end of the legacy spectrum may require significant work to mitigate constraints that will be around for many years to come.

Ability To Integrate

Legacy systems typically rely on older integration methods (or none at all) to share data and may not be capable of providing data in modern formats such as XML. This does not inhibit integration; it only reduces flexibility, and increases complexity and cost. You need to understand the constraints of each legacy system in your Smart Grid solution and design accordingly.

Data Structure

Constraints in field formats, field lengths, table structures, null values, leading zeros, etc. are important details that can make legacy system integration a challenge. Newer integration layer technology makes accommodating the constraints of the legacy system possible, but no less tedious. As always, the devil is in the details. And typically, changing these constraints in the legacy system is not an economic option.

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