Enterprise GIS and the Smart Electric Grid

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Electric utilities face serious challenges. As normal demand continues to rise, the transportation sector looks to electricity to answer fuel concerns. The CEO of a major U.S. electric company predicts the impending electrification of the transportation industry. We are seeing more and more hybrid vehicles, and several major automakers plan to offer plug-in hybrids in less than two years. Should a significant increase in the use of electricity for transportation materialize, as it likely will, demands and electric energy usage will soar. Meanwhile, the existing electric infrastructure continues to age. Soon, a significant number of the utility workers will reach retirement age. In all likelihood, regulators outside Europe will institute a new carbon cap and trade system in 2009, causing electric utilities to rethink nearly every process they perform. Increasing customer demands, the need for additional physical facility security, and the ever-present objective to keep costs under control will force utilities to operate differently and more intelligently.

Many utilities will implement smart grid technology to cope with changes and challenges. In December 2007, United States president George W. Bush signed into law the Energy Independence and Security Act (EISA). Title 13 of this law is called Smart Grid, so the United States government officially recognized the term. Other terms for smart grid are "intelligent grid" and "intelligent utility network." All these terms mean the same thing.

What Exactly Is a Smart Grid?

A smart grid is not a piece of hardware or a computer system but, rather, a concept. As its name implies, the smart grid is about an intelligent electric delivery system that responds to the needs of and directly communicates with consumers. While there are many facets to the concept, the smart grid is really about three things: managing loads more effectively, providing significantly more automation during restoration after an outage event, and enabling more interaction between energy providers and consumers.

How Does a Smart Grid Answer the Electric Industry's Challenges?

A smart grid gives utilities more time to increase capacity, improve energy efficiency, and help lower greenhouse gas production. By managing loads, utilities can better leverage their lower-cost and better-performing generating plants to reduce fuel consumption and greenhouse gases and gain higher utilization of existing equipment.

Electric companies will know the consumption of individual consumers at any given time because smart grid technology helps markets interact with consumers. Utilities will give consumers price signals and information about the implications of their energy usage. For example, customers could discover the price (or cost) of turning on their air conditioners. A smart grid could detect areas of theft of current and take measures to cut off supply.

The electric system will adapt to new conditions without human intervention once a smart grid is in place. If a circuit were nearing its load limit, the smart grid could take action to automatically reconfigure the network in an attempt to relieve the overloading condition. The grid can be "self-healing" by switching around problem areas to minimize outages.

Since electricity demands tend to spike during the hottest part of the day and year, electric companies have to maintain large reserves of capacity. A smart grid makes best use of resources. By allowing the grid to smooth out the demands, utilities can better utilize existing facilities.

With thousands of sensors and operators equipped with a better understanding of the way the system is running, a smart grid is predictive rather than reactive to prevent emergencies. A smart grid will supply operators with the tools to predict a failure before it happens. Appropriate action may be automatic. Even with today's sophisticated SCADA and distribution management systems, operators do most of the switching based on individual interpretation of the situation.

What Are the Main Drivers of the Smart Grid?

Three market- and consumer-related issues are driving interest in smart grid technology.

Greenhouse gas reduction: In response to growing concern over climate change, smart grid technology will contribute to the utility industry goal of cleaner emissions. It will do this by flattening peak demands, thereby reducing the need for less efficient and more environmentally damaging plants to come online just to meet the peak demands.

Customer price signals: Smart grid aims to create an understanding among consumers that electricity pricing varies significantly during the day. Allowing consumers to readily see this will influence their behavior, perhaps initiating wiser use of energy.

Integration of renewable energy sources: The two most common sources of commercial renewable energy are wind and solar rays. Both are intermittent and tend to be more geographically dispersed than conventional power generation. So the grid will have to be smarter to deal with these less-conventional energy sources, especially as they become more prevalent.

How Do Utilities Use the Smart Grid?

Utilities will need additional components to employ the smart grid. Some of these components are described here.

The key to the smart grid is the complete installation of **smart meters** that provide a link between consumer behavior and electric energy consumption. A smart meter is an electric meter that measures consumption for a very small interval of time (seconds or less), saves that data to memory, and communicates directly with the utility. The smart meter can also communicate energy use to the consumer. Some smart meters can automatically disconnect the load and block power from flowing.

For a smart meter to work, there must be a link from the meter to devices within the consumer's home or facility as well as communication between the smart meter and the utility. Many electrical appliances are equipped with internal devices that connect to smart meters. Smart meters will be able to communicate and even control devices within the consumer's home or business. When there is a power failure, the smart meter alerts the utility of outages. During a peak power emergency, the utility tells the smart meter to shut off selected loads as allowed by tariffs. Since smart meters are not limited to measuring electricity, we may see smart meters used by gas and water utilities as well.

A smart grid will require **energy storage systems** to level the peak and enable utilities to access the most efficient and environmentally sound power generation options. Energy storage systems could be enhanced batteries, flywheels, or compressed air systems.

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Most **outage management systems** (OMS) use sophisticated prediction engines based on customer phone calls and network models to determine outage locations. An OMS linked to a smart grid will rely on a sensor network for faster, more accurate response.

In a smart grid, the OMS will converge with the **distribution management system** (DMS) to form an automated analytic engine. The DMS provides the means to reconfigure and analyze the electric network. A DMS integrated with an OMS will enable utilities to make decisions based on information from the sensor network and smart meters about loading, predictive equipment failures, outages, and restoration.

In most electric utility systems today, the utility is virtually blind to problems in the field. The smart grid will have **sensors** to detect fault, voltage, and current along the distribution network and communicate with the central smart grid processors. Most electric systems around the world are able to communicate very little about the state of the system other than the main supply substations.

The crux of the smart grid is the ability to communicate the state of the system from the **sensor network** to both the utility and the customers. The electric distribution system will grow from a single network to an integrated dual network system. One network will represent the power system, and the other will represent an advanced communication network.

Utilities need a means of collecting data from the sensors and smart meters to make decisions about self-healing the grid, load shifting, and billing. Self-healing means that the electric distribution system will configure itself to limit the extent of customer outages without human intervention. A sophisticated **data management system** will store historic and current real-time data about the system from meters and sensors.

Traditional **SCADA** systems are early smart grid technologies. However, the reach of SCADA is usually limited to substations and a few major distribution automation devices like remote-controlled disconnect switches. The data managed by SCADA plays an important part in any smart grid implementation.

A smart grid will need **real-time analytic engines** able to analyze the network, determine the current state and condition of the system, predict what may happen, and develop a plan. These engines will need data from the utility and outside parties such as weather services.

The combination of smart meters, data management, communication network, and applications specific to metering is **advanced metering infrastructure** (AMI). AMI plays a key role in smart grid technology, and many utilities begin smart grid implementation with AMI.

A critical facet of the smart grid is the underlying electric and communications network. An **enterprise geographic information system (GIS)** provides the tools, applications, workflows, and integration ability to support the smart grid.

The Critical Role of Enterprise GIS in Smart Grid Technology

GIS is widely recognized for its strong role in managing traditional electric power transmission and distribution and telecommunications networks. GIS will likewise play a strong role in managing the smart grid. For utilities, GIS already provides the most comprehensive inventory of the electrical distribution network components and their spatial locations. With the smart grid's sophisticated communication network superimposed on the electric network, data management with GIS becomes utterly critical.

Enterprise GIS is a framework or platform that underpins an electric utility information technology system. Other platforms that make up the utility IT system include SCADA, customer billing/financial systems, and document management systems. Enterprise GIS authors, or creates, spatial information about utility assets (poles, wires, transformers, duct banks, customers) and serves that information to the enterprise. The core business applications then mash up, or combine, the data served from the GIS, SCADA, and customer systems along with other information from outside the utility such as traffic, weather systems, or satellite imagery. Utilities use this combined information for business applications, from visualizing a common operating picture to inspection and maintenance to network analysis and planning.

GIS will help **manage data about the condition of utility assets.** After parts of the system go into service, utilities must manage the system through the collection and maintenance of asset condition data. Some condition data can come from automated systems, and other data can come from inspection systems. Utilities are rapidly adopting GIS-based mobile devices for inspection and maintenance. Enterprise GIS, with its desktop, server, and mobile components, allows utilities to gather condition data.

The power of GIS helps utilities **understand the relationship of its assets to each other.** Since the smart grid is composed of two networks—electric and communications—utilities must understand physical and spatial relationships among all network components. These relationships will form the basis for some of the advanced decision making the smart grid makes. A smart grid must have a solid understanding of the connectivity of both networks. GIS provides the tools and workflows for network modeling and advanced tracing.

GIS also helps utilities **understand the relationship of networks with surroundings.** Because GIS can help identify relationships between systems and the environment, it is an essential tool for restoration, storm tracking, and security monitoring.

From a smart grid perspective, GIS allows utilities to **visualize the electric and communications systems** and the relationship that exists between them. It goes well beyond the traditional "stare and compare" method commonly used by utilities to a notion of seeing relationships. GIS provides a means to monitor and express the health of the system in an obvious way with commands such as, "Show me all the sensors that have failed to report results in the last hour." GIS can show the real-time view of the grid and note where things are changing. In effect, GIS (as compared with a SCADA system) shows the complete state of the grid, represented by a realistic model in a way that people understand.

GIS is used to **determine optimal locations for smart grid components.** During the rollout of a smart grid, utilities will need significant analysis to determine the right location for sensors, communication-marshaling cabinets, and a host of other devices such as fiber optics in conduits and on poles. GIS provides the proper means to perform these design services, since the optimal locations depend so heavily on the existing infrastructure.

GIS can **provide a spatial context to the analytics and metrics of a smart grid.** With GIS, utilities can track the metrics over time and provide a convenient means of visualizing trends. Since a smart grid is supposed to be smart, it must be able to provide advanced grid performance analytics, track trends in equipment performance and customer behavior, and record key performance metrics.

As the heart of the distribution system, GIS can actually **control parts of the grid.** The technology can recommend ways to get the grid back to normal after an abnormal event. Or it can automatically have the grid do something different. A smart grid driven by a GIS would adapt to changes based on information from the thousands of sensors to help prevent outages and equipment failure. For example, in the United States, utilities do not monitor the vast majority of distribution transformers. If the load on any of these transformers rises beyond capability, they can fail. With monitoring, the smart grid would be able to determine whether the transformer has experienced past stresses and therefore lost longevity. As the transformer approaches a dangerous limit, the smart grid could take preventive measures to avoid the catastrophic failure of the transformer. Within GIS, operators would then perform a spatial analysis to determine the risk of failure and customer impact. The smart grid algorithms, in concert with the GIS, could determine whether to reduce the load at customer sites, reconfigure the network to relieve the load, or perform preemptive switching.

Utility Challenges

It is hard to imagine implementing a smart grid without a detailed and comprehensive network model contained within the GIS. Utilities must face a number of challenges to ensure the effectiveness of a smart grid program.

The **data quality** that exists in the GIS must be outstanding. It is one thing to have a few errors on a planning or asset management map. While not desirable, it is even somewhat tolerable to have some inaccuracies in the GIS data that feeds outage management systems. However, it is not acceptable to have incorrect data in a system that automatically controls the electric distribution system. Errors could result in increased outages or, worse, accidents. Utilities must carefully examine their data-updating processes and quality assurance procedures.

There are a number of excellent **standards for processing critical infrastructure data.** Those standards and processes should be tested and strictly adhered to. Historically, utilities maintained a large backlog of documentation about completed work in the field (as-built sketches and accumulated work orders) to be posted to the GIS. Utilities must measure the time spanning from when a change occurs in the field to when the change is reflected in the GIS. For example, if the utility installs and energizes a sensor, the GIS and the smart grid algorithm must reflect the data about that sensor in a relatively short period of time. As the time increases from seconds to minutes to days to weeks, so does the risk of something going wrong.

Utilities are now able to **build a GIS on an accurate land base.** Since GIS has been used by utilities for more than 20 years, it predates GPS. Utilities that continue to base facility location on antiquated grid systems will not be able to successfully use GIS until they make the land base and facility information spatially correct. There are advanced tools to assist in the corrective process, but it is still highly labor intensive and time consuming. For utilities that have not yet built a comprehensive GIS for infrastructure, the goal should be an accurate, GPS-compliant land base.

Lack of **a digital model of the electrical system—**whether urban, overhead, underground, networked, radial, or some combination therein—will limit the overall effectiveness of the smart grid. Some utilities have built a GIS piecemeal, with some parts of the service territory converted to digital form and others still in CAD or even paper form. Many have only converted primary data and not secondary networks. Others have converted rural overhead areas but have not converted urban networked areas. The piecemeal approach is not effective if GIS is to be the heart of a smart grid. Installing smart meters in areas where the utility has not modeled the electric network will inhibit much of the usefulness of the equipment. In this case, the use of the smart meter would probably be limited to billing.

A large problem for utilities is the lack of **good customer addressing information.** Even in countries where virtually all premises have a physical address, utilities struggle to keep data current. Some utilities don't have tight processes to make sure new customer data is linked directly to the GIS. If GIS does not have an exact correlation of the customer premises and the electric system, any hope of automation and self-healing will be lost. In regions where customer addresses don't exist, utilities will need to create some kind of coding system that uniquely identifies a customer location to a point in space and to the electric distribution system. Otherwise, it will be impossible to build a smart grid. Once the system is in place, it is critical that utilities have a foolproof quality assurance process that guarantees that as they add new customers to the system, those customers are reflected as connections to the electrical network.

GIS Makes the Smart Grid Smart

Since the idea behind the smart grid is to add more **monitoring capability and control to the electric system,** enterprise GIS is fundamental to its success. It is imperative to have a solid model of all electric assets including their condition and relationships to each other, to customers, and to the telecommunications systems that will drive the smart grid. Utilities must have processes and procedures in place to ensure accurate and timely GIS data so that the smart grid will be able to make automated decisions based on correct information. Today, utility dispatchers make the vast majority of switching decisions based on human interpretation. Without human intervention, the smart grid must rely on a near-perfect GIS model of the electric system.

GIS is indeed a **transformational technology.** In concert with smart grid technologies, such as advanced sensors, smart meters, energy storage devices, and renewable energy systems, GIS will certainly contribute to the transformation of the grid from a largely passive and blind system to an interactive, intelligent one. Smart grid technology will communicate with consumers and consumer devices and make alterations to help lower costs, improve equipment utilization, and reduce carbon emissions. To do this, utilities should fully integrate GIS into the overall IT framework.

Finally, GIS is a wonderful tool to help in the **deployment of the smart grid** itself. Utilities can monitor construction progress, route crews in the most efficient way, and help with analysis for locating the best location for repeaters, sensors, and new communication backbones.

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