Creating Your Smart Grid

A HOW-TO GUIDE



Secure, Manage, Integrate, and Extend Your Smart Grid Network with Communications Technology

Produced by GOVERNMENT TECHNOLOGY SOLUTIONS FOR STATE AND LOCAL GOVERNMENT

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Smart Grids Moving Forward

In the world of electricity delivery, there's the grid. And then there's the smart grid. Smart is better. By enhancing the power delivery process and collecting real-time data from within the electrical grid and from consumers, utilities can operate more efficiently and cost-effectively than ever before.

Utilities have done a great job of providing safe, reliable power for homes and businesses. But many grids have been in place for decades. Their aging infrastructures could use some help, and today's communications technologies provide unprecedented improvements.

Automated processes at substations, faster routing around outages, smart meters in homes and other improvements will benefit everyone with a stronger, more flexible grid — a smart grid. The new grid will be safer, more reliable, more efficient and less costly to operate. It will also be more secure.

A smart grid is made possible by robust, end-to-end communications technologies. These technologies, working alongside the electrical grid, pull in data from all over the grid. Sensing devices are placed throughout the electrical grid and in consumers' homes and businesses. Information from the devices are sent to applications that can read and act upon the data.

The sensors send alerts about problems, grid performance statistics, status updates and more. Utility applications absorb the data, interpret it and help utility personnel make better decisions regarding the delivery of electricity.

The smart grid is a "network of networks," or a "system of systems." It is new, it is complex and it will take some time to design and implement. But the benefits of real-time information using communications technologies have been seen again and again in other industries. They are mature technologies, and they can solve many problems utilities face today — by improving awareness of grid conditions in real time for enhanced decision-making and control.

This guide shares numerous challenges and opportunities as the transformation to a smart grid moves forward. The smart grid is the future — and in some cases, the present. Initial capabilities are already up and running in some cities and states. But for most places, now is the time to prepare for the coming smart grid. It is time to plan for a brighter, safer, more reliable future. It will take a lot of work. But it will be worth it.

Challenges and Opportunities for Utilities

Utilities are facing unprecedented challenges, including increasing demands for energy. The solution cannot be to simply build additional power generation facilities. There are numerous reasons why this approach is not sustainable, including the cost of new generation facilities, the time it takes to build them and public concerns of environmental impact.

Thus utilities are looking for more innovative ways to balance the inequality between power supply and demand. Traditionally utilities only controlled the supply. But today, utilities are implementing innovative approaches to engage consumers in order to also manage demand. They are investing in alternative energy supplies to supplement traditional generation, such as solar and wind power. Consumers are also becoming suppliers through micro-grids that provide localized generation of power that can be fed into the grid.

Providing electricity requires more than just managing supply and demand. Consumers also expect that power always be available. Power quality must also be guaranteed, because poor power quality can result in malfunction or damage to electronic devices. In an effort to reduce outages and increase quality of service, it's becoming more common for utilities to face penalties if quality of service falls below predetermined levels.

Finally, while utility capital expenses are generally funded through rate plans, operational expenses are a more variable cost that can reduce profits for Investor-Owned Utilities or result in higher than anticipated costs for co-op and municipal utilities. This means utilities need to reduce their operational costs through more efficient operations.

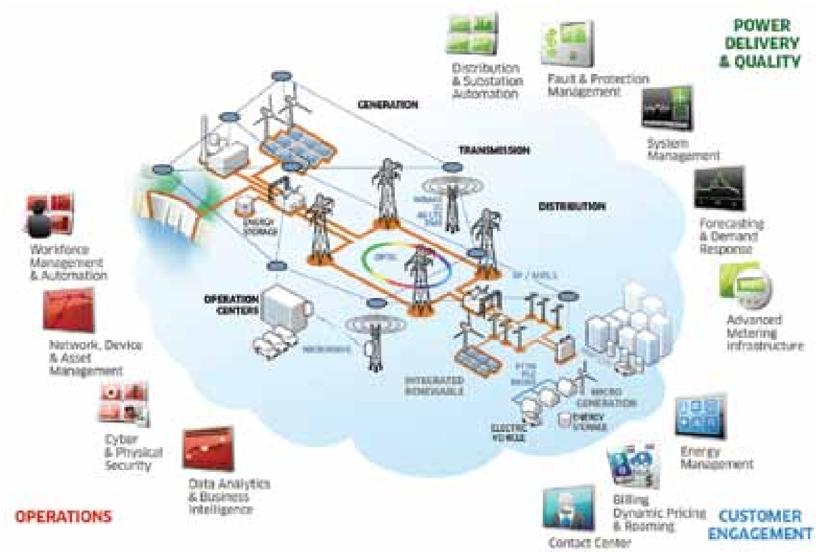
The smart grid creates the opportunity for utilities to address all of these challenges using a common technical foundation. At the heart of the smart grid is a secure, reliable two-way communications network that enables real-time monitoring and control throughout transmission and distribution grids. With this foundation, utilities can address their key challenges using the techniques shown below.

Improve Power Delivery and Quality	▫ Automated load balancing ▫ Power quality management ▫ Automated switching and protection systems
Increase Operational Efficiency	▫ Automation of asset monitoring and management ▫ Analytics for decision support ▫ Connected mobile workforce
Incorporate Green Energy	▫ Monitor and control renewable energy sources everywhere ▫ Maintain grid stability as renewable energy sources are added ▫ Meet environmental targets and regulatory requirements
Engage Customers in Energy Management	▫ Information and incentives for reduced or more intelligent energy usage ▫ Direct load controls ▫ Improved customer service

Of course, implementing the smart grid requires careful planning and a holistic approach if all of these objectives are to be met. The communications network at the foundation of the smart grid needs to be flexible enough to support the new applications. It must be extended deep into the distribution grids so that it has ubiquitous coverage and can support millions of monitoring and control points. It needs to provide predictable performance, despite the inherent unpredictability and evolving requirements of smart grid applications. It needs to be secure. And it needs to be manageable. The remainder of this guide focuses on how to meet those needs.

ADDRESSING THE CHALLENGES VIA COMMUNICATIONS

To satisfy the challenges posed to today's energy utilities, there are three key areas that must be addressed: **Power Delivery and Quality**, **Operations** and



Customer Engagement. The following diagram lays out the relationships among these three areas.

Improve power delivery and manage power quality. To improve in these areas, utilities must have access to real-time information about what's happening on the grid. That information will come from hundreds of thousands of devices being placed on the grid. The resulting smart grid, with its *automation in both substations and distribution*, will provide decision-makers with more information than they have previously had, very quickly.

Consumers want to know they can count on the power always being up and running. The smart grid's data collection and automation will reduce the number and length of power outages. Managing this power quality will be easier using state-of-the-art *fault and protection management systems*, supported by sensing devices sending data from throughout the grid. However, for this collected information to be truly useful, utilities will need to be able to correlate data coming in from a wide variety of sources. Data from a single device is not nearly as meaningful as aggregate data collected from across the grid and then analyzed. Correlation software makes sense of the data and puts it into a form that utility personnel can use to make better decisions.

System Management is about balancing power supply and demand. With the volumes of embedded renewable energy, particularly from intermittent sources such as wind and sun, finding the right balance requires the utility to have greater familiarity with the end user. The smart grid, through *Advanced Metering*

Infrastructure, enables utilities to learn more about their customers — including how they use electricity, how they prefer to adapt to changing conditions and more. Greater amounts of data from customers can help the utility fine-tune its decisions about when to generate more power, when to buy additional power from the energy market or when to make use of *Demand Response*. The result is more efficient management of power and improved *forecasting* of supply and demand.

Optimize operations. For an electrical utility, there are numerous operational challenges in the field. Building a smart grid includes deploying hundreds of thousands of new devices into the electrical infrastructure. *Data Analytics & Business Intelligence* will help a utility make sense of the vast volumes of data being created by these devices and will enable it to manage its energy network to the highest levels of safety, reliability and efficiency. An experienced network integrator can often be a huge help. Having a partner that's experienced in building communications networks can reduce the chances of encountering problems in the field.

An end-to-end approach to security — both *physical and cyber security* — is another way to improve operations. This will reduce the number of vulnerabilities, standardize security processes, and create a more reliable and robust system that can be simpler to operate. It will protect the combined electricity and communications network against failure due to malicious or accidental activities of third parties outside the control of the utility.

Operations are about *managing the energy network and its assets*. This is increasingly complex as the network becomes ever more intelligent and as new energy sources are deployed throughout the network. Strong communications and data management strategies are crucial to optimize operations and make the best use of existing assets.

Often there is risk involved in utilizing too many technology platforms. For example, having five systems in a network means buying equipment from five different vendors. Again, partnering with a strong network integrator that can share the risk with the utility can result in a better mitigation plan for adapting to change and managing unexpected events.

Another operational challenge is *workforce management and automation*. Utilities must have people out in the field, and strong mobile communications can give mobile workers access to the information and tools they need, no matter where they're located. They need to be able to share information quickly.

Customer engagement is the third key area to a successful smart grid implementation. Traditionally the consumer has been passive, taking little or no interest in the delivery of electricity to the home, office or factory. This is changing. Already corporations are implementing local renewable energy sources that can feed surplus energy production directly into the grid. Increasingly this is extending to the residential user with micro-generation plants on the roofs of their homes. On top of this, many utilities are looking at demand response and similar mechanisms to make optimal use of their existing assets.

This creates an increasing need for localized *energy management* that will allow consumers to make their own choices about how they manage their energy consumption. At its most simple, this can be characterized as a choice between comfort and economy, especially as utilities move to *dynamic pricing* models. Electric vehicles accelerate the dynamic change that the consumer is making, bringing greater need for *billing* flexibility and for commercial energy *roaming*.

With a stronger relationship between utility and customer, utilities can also help customers save money. The utility can advise customers to avoid using electricity during peak times, which will lower their bill and save the utility money as well.

This shifts the end user from a "consumer" to a "valued customer." This transformation alone will require major changes in how the utility handles customers and its *customer contact*. In this process, the network integrator — through provision of communications and data management services — will play a key role in making sure utilities are ready and able to make the necessary transformation in their customer management strategies.

Preserve integrity of existing applications while introducing the smart grid. A key challenge when moving to the smart grid is making sure older applications work smoothly alongside new ones. It would be impractical for utilities to throw out all of their existing systems at once. There will be a long transitional period, potentially measured in decades, where old and new applications must co-exist and work together. Many of these applications involve controlling and managing grid networks. The choice of technology is key, since it is essential that the upgraded communications infrastructure interoperate seamlessly with today's energy applications and their current communications environment.

Control costs. Communications technology, and taking an end-to-end approach to the smart grid, can lower costs in many ways — reducing infrastructure maintenance, speeding up processes, creating immediate scalability and much more. Another way to control costs is to work with an experienced partner employing open standards technology. There are numerous vendors producing products based on open standards. An open-standards approach leads to lower cost for utilities. It can be expensive when utilities work with proprietary networks and devices that don't interoperate with other systems.

Sweat the existing assets. Networks were often built on a theoretical maximum capacity and a theoretical predicted load. Communications and data management technologies allow utilities to measure in real time the real capacity of a segment of the network (generally driven by climatic conditions). This in turn enables the asset to be utilized to its fullest extent, often allowing utilities to postpone expensive re-engineering of network lines and transformers.

BUILDING THE FOUNDATION

Communications technology is a key part of the answer to many of the challenges utilities face. The latest communications technology solves many problems at once. Utilities can gain improvements in safety, reliability, cost, efficiency and security by moving to a smart grid enabled by strong communications technology.

The smart grid involves numerous new applications. A robust communications network is crucial to enabling those applications to perform at their best. That means creating an environment where data is collected efficiently, organized quickly, and then used to control and operate grid functions in the best possible manner.

Automation is an important part of the smart grid's effectiveness. Many key functions can happen automatically — for faster responses to changing conditions, more efficient collection of data and immediate alerts when things go wrong.

The right communication technologies can help maximize the safe, reliable and secure delivery of power via a smart grid. Following are some tips.

Create an end-to-end strategy. While it may be tempting to build a network for substation automation only or distribution automation and nothing else, the best use of today's technology is to take an end-to-end approach to your architecture. Look at the entire grid and then build a communications platform that's robust and flexible.

Gather and leverage information. The tools are available today to collect and analyze tremendous amounts of data. The more information a utility can collect — and organize into a meaningful form — the safer the grid will be. Having more information, and understanding it, will help keep a utility's people and equipment safe. The latest technology also makes the grid more reliable — improving real-time visibility into operations, making grid conditions more predictable and automating responses that limit the impact of outages.

Engage customers in energy management. Utilities on a smart grid are connected to a tremendous resource — their customers. By gathering information about customers and their energy usage via the smart grid, utilities can help those customers modify their behaviors — so customers can save money and the power grid can operate more efficiently. Utilities can help customers move some of their electrical usage to off-peak hours, which are typically nights and weekends. The result is improved demand response. Both the utility and its customers are better able to respond to changing conditions. This makes it easier for the utility to manage supply and demand.

Use technology to the most effective point. It's often too expensive to use the same communications technology all the way from a generation station to a consumer's home. It's much more affordable to use multiple technologies along the way. For example, fiber optics may be a good choice from generation through transmission, but it's usually too expensive to also deploy it throughout the distribution part of the grid. So it can be best, for example, to put in fiber to the most economically feasible point, and then go to something less expensive such as wireless communication.

Automate your distribution. Traditionally, distribution networks haven't been as heavily monitored as transmission networks. That's because transmission has so much more energy flowing through its lines. With the smart grid, much more attention can be paid to distribution. Putting controls on capacitor banks, pulling in data from devices out on the poles and monitoring transformers in residential neighborhoods are some of the tasks enabled by new communications technology. Distribution automation applications provide a more in-depth look into the grid than utilities have ever had before.

Automate your substations. Substations are a critical part of the grid, and utilities need to know what's happening within them. High- and medium-voltage substations especially should be connected to the smart grid. Substation automation gives a detailed view of what's happening with insulators, lightning arrestors, capacitors, relays and other equipment. With the smart grid, utilities can have two-way communication with all of these devices 24 hours a day.

The communications network can also help with other needs, including carrying signals from security video cameras; communication with building access devices; and providing voice, Internet and other connections for mobile employees such as maintenance personnel.

The architecture for substation automation can vary greatly. In some cases, it could include cameras, secure Wi-Fi access points, an Ethernet network and a serial network. It could include variations combining some or all of these elements with others. Much of it depends on the specific substations, the particular equipment they house and their locations.

Improve SCADA. Supervisory control and data acquisition (SCADA) has long been a key tool for utilities. SCADA systems collect data that's vital to properly controlling equipment and conditions within the electrical grid. The smart grid will take SCADA further, collecting more detailed information from more devices — providing a deeper understanding of the grid's condition.

Integrate distributed generation. The traditional one-way flow of energy is changing to a new, two-way model. As customers put solar panels on their homes or wind turbines on their farms, for example, they generate renewable energy that can be added to the grid. Sensors can help the smart grid absorb, and control in real time, these new supplies of energy in an efficient manner — enabling generation points upstream to be able to adjust their outputs accordingly.

Integrate smart meters. Smart meters — also known as Advanced Metering Infrastructure (AMI) — are being installed in homes and businesses, replacing traditional mechanical meters. Smart meters collect important energy usage data and provide the means through which utilities can communicate with customers. Smart meters help utilities look deeper into the grid, giving the opportunities to make it run more smoothly.

Improve disaster recovery. It's critical for utilities to have backup data centers, or to mirror data in separate disaster recovery locations. The smart grid will generate much more data than utilities have had in the past. Protecting data and systems is more important than ever. Disaster recovery keeps the electrical system on track despite natural and man-made disasters.

Optimize your workforce with better mobility. Whether it's dispatching someone for basic maintenance, or responding to a downed power pole in a storm, utilities need to be in contact with mobile field workers. While many utilities have relied on land mobile radio (LMR) systems (or professional mobile radio (PMR) in some regions) for communication, newer technologies have proven to be much more productive. Today, mobile workers with smartphones can access internal applications to find information they need within seconds. That can be much faster than calling someone on the radio and asking for help. Utilities need to have a strong communications network that will support today's mobile workforce. Providing connection to a virtual private network (VPN) can provide mobile workers with secure access to email, databases and anything else they need, no matter where they are. When building a smart grid, incorporate strong communications for mobile workers.

Extending the Smart Grid Deeper into Distribution

Today's communication technologies give utilities an unprecedented opportunity to connect with their customers. Along the way, utilities are also putting more sensors farther out into the distribution network. The smart grid gives utilities, for the first time, a deeper knowledge of what's happening at the outer edges of the network.

With data coming in from farther out than ever before, utility managers have more information and can make better decisions. Utilities can also respond to outages and other issues more rapidly, because they can see more quickly where problems are originating. Utilities also can create better relationships with customers by extending their networks more deeply into distribution.

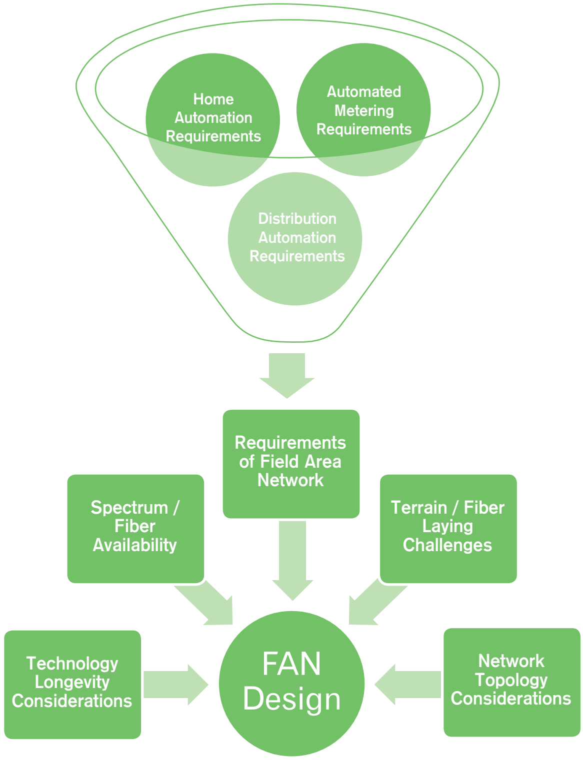
Field area networks (FANs) extend the smart grid in an economical fashion. They use a variety of technologies working together seamlessly to create a cost-effective connection to growing numbers of data collection points. The collection points gather data directly from homes and businesses via neighborhood area networks.

FANs support substation automation, distribution automation, voltage optimization and other operations within the grid. FANs enable the use of smart meters, and transmit real-time data related to network performance to help prevent outages. They extend performance and quality-of-service levels from the core network all the way out to endpoints. FANs also enable scalability, so the network can grow as new homes and businesses are built within their areas.

BUILDING A FIELD AREA NETWORK

A FAN usually consists of several types of technologies, combined to provide the best, most cost-efficient solution for a given area. The FAN provides the means by which data collection points can be connected to the core network, so the many new smart grid applications can be used. The FAN supports command and control of devices in substations, on power poles and at other points in the distribution grid. Following are some tips for building a field area network.

Network Requirements Analysis



Know your requirements. When building a FAN, it's important to do a careful analysis of requirements. The first step should be to identify the network requirements for each application, including the bandwidth, latency, availability and security. Also consider scalability needs, to accommodate future applications.

Consider Applications. Keep in mind the new applications that will be part of the smart grid. Consider performance requirements for applications, under various conditions.

Choose the right technologies. There are a wide variety of wired and wireless technologies that can be used when building a FAN. When deciding what to use, it's important to understand several key factors regarding the area being served. Some of these factors are wireless broadband spectrum availability, population demographics, population density and topography. Also consider whether there is existing infrastructure, such as communication towers, that can be incorporated into the FAN. Most utilities have two-way LMR/PMR towers that can be re-used — if they're in the right locations.

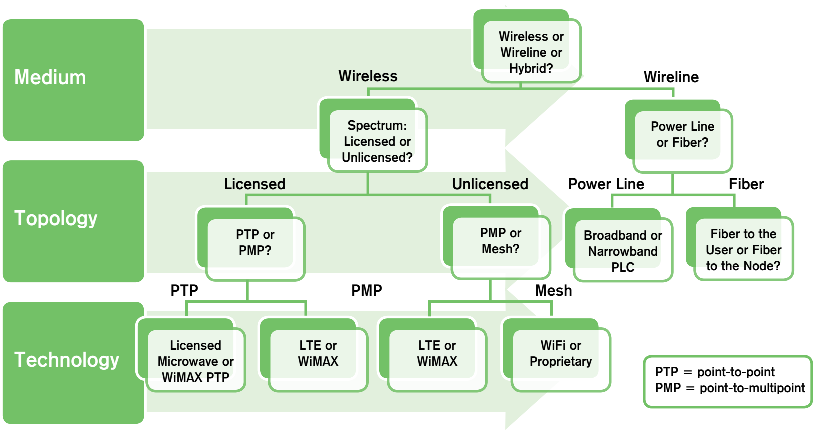
Do an RF analysis for wireless. Are others using a close frequency nearby? Will there be interference from other sources? What kind of performance can you expect from your system? Analyzing the radio frequency landscape is an important part of understanding what's possible in any given area.

Focus on network sustainability. Make sure your solution is something that can be sustained for many years without interruption. Use equipment that's based on open standards, so you don't run the risk of being stuck with one provider that can interrupt your activities if it's having problems of some kind.

Go wireless. Three of the top choices for FANs are WiMAX, Wi-Fi mesh, and Long Term Evolution (LTE). While WiMAX is popular with utilities today, many experts agree that the speed and other benefits of LTE will make it the technology of choice in the future for the smart grid.

Don't forget wired network. Wired options include digital subscriber line (DSL), power line carrier (PLC), broadband over power line (BPL) and fiber to the x (FTTx) ("x" meaning "home," "premises," "user" or a variety of other destinations). Sometimes even fiber to the home can be economically feasible. For example, bringing fiber to the home enables the owner of the fiber to recoup expenses by leasing some of the capacity to support cable TV and other entertainment, phone or Internet services. This can be an attractive option in areas that lack broadband Internet and TV service provider presence. Alternatively, if PLC is chosen, utilities can use the same infrastructure they're using for delivering power to also deliver communications.

FAN Technology Decision Tree



Manage deployment complexity. The deployment of elements within the FAN involves many “moving parts.” Managing the complexity of this includes being prepared for unpredictable events. For example, there may be more buildings in the way of the FAN than expected, which can affect the RF engineering. Or, there may be more users in the area on the same spectrum. Be ready for changes and challenges during deployment.

Designing wireless networks can be particularly challenging in mountainous or heavily wooded regions, or in urban areas with tall buildings. It’s important to validate the design with site surveys and signal-level measurements. Use the data taken from these studies to make any necessary adjustments to the design. When conducting frequency planning, consider both existing and potential future users of the spectrum.

Make the FAN secure. Security should include encryption and authentication. Encryption protects the integrity and confidentiality of the data, and prevents unauthorized people from accessing sensitive data. Authentication keeps rogue users and devices off the network.

Ensure high availability. Just like the core network, a FAN should be designed with high availability in mind. Utilities should strive for rock-solid availability and no outages or performance failures.

Integrate backhaul. A backhaul network moves data from elements on the FAN back to the core network. Backhaul can be built on fiber optics, microwave radio or other technologies. A utility could have its own backhaul, or it could lease one from a commercial provider. When making backhaul plans, be sure to do an assessment of existing infrastructure in the area.

IMPROVING COMMUNICATION WITH CONSUMERS

Any business, government or utility would want to know more about its customers. If you know your customers better, you can serve them better. Utilities have a tremendous opportunity to know their customers better via the smart grid.

Smart grid technology takes utilities inside homes and businesses. Smart meters can tell utilities a lot about how a consumer is using energy, and when. With this knowledge, utilities can help consumers better understand their own behaviors, and the costs associated with them.

Energy consumers are human. They often don’t realize they can save money by modifying their behavior — until the utility points it out to them. With this new knowledge, consumers are often happy to move some of their activities to

off-peak hours. This saves them money. Many consumers changing their habits lessens the load on the grid, enabling it to run more smoothly and potentially allowing utilities to defer major capacity upgrades.

Create real-time communications. Through the smart grid, utilities can inform customers when to modify their behaviors in real time. They can suggest reducing the air conditioning during peak hours on a hot day. Or with direct load controls, utilities can make the changes themselves, letting consumers know they'll adjust thermostats remotely — if the consumer has agreed to participate in such a program. These alterations can occur quickly, as needed, because the smart grid provides real-time communication between utility and consumer.

Improve demand response. Utilities typically determine demand response based on historical data that includes information on consumer behavior, usage patterns, the impact of weather conditions and other factors. Thanks to the direct connection via the smart grid, utilities have better information from consumers and can thus make smarter decisions regarding their response to energy demands. They can also make more accurate predictions about the results of a response.

Preserving Existing Applications While Introducing the Smart Grid

Utilities have spent decades building their infrastructures. Embedded in their networks are equipment and applications from long ago. As utilities move to the smart grid, they're faced with the challenge of integrating old equipment and applications with new technologies. The next few years will be a period of integration. Since new applications for operating and managing power delivery are a crucial element within the smart grid, getting the new applications to work with the old ones is extremely important.

Is IP the answer? The smart grid requires putting new devices into the distribution network — the key link between transmission and consumption. It also requires a great deal of interoperability between a variety of both old and new control and monitoring devices, control systems and business systems. Internet protocol (IP) technology is the communication standard for which new smart grid devices and applications are being developed. But IP alone cannot adequately support some mission-critical communication, due to IP's inability to provide the predictability and reliability required by these applications.

Historically, utilities' private communication networks used time-division multiplexing (TDM) technologies such as Synchronous Optical Networking/ Synchronous Digital Hierarchy (SONET/SDH). This was due to SONET/SDH's low latency, high availability and strong predictability. But TDM is not very flexible, and doesn't make efficient use of available bandwidth. If there's no communication over TDM, circuits become idle, yet aren't available for other applications to use.

Meanwhile, utilities have a well-founded concern about whether the new IP-based networks can meet performance requirements for mission-critical applications. Key applications like teleprotection and SCADA have been in place for a long time, and they often run on older technologies like TDM, serial and analog. But these technologies will not migrate to IP overnight.

What utilities need is a way to combine the flexibility and scalability of IP with the predictability and reliability of TDM. They need a communications architecture that seamlessly supports both traditional communications for supporting existing applications and new IP communications for the smart grid. IP and multiprotocol label switching (MPLS) together are the answer. IP/MPLS enables the integration of new applications and allows old and new applications to work side-by-side on a common network. IP/MPLS also brings numerous other benefits to the smart grid — including reliability, security and manageability.

Following are tips for building a communications foundation to effectively support traffic for both current, and emerging, smart grid applications.

Make IP predictable using MPLS. IP on its own is a non-deterministic technology; you can't really determine a route that a specific data packet will take when it's sent across the network. Nor can you determine the amount of time it will take to get there. That's not as predictable as utilities require for mission-critical operations traffic, but when you support IP communications over an IP/MPLS network, that problem is solved.

MPLS places IP data packets into MPLS packets. MPLS packets are assigned labels that are used by the network to send the data along pre-determined paths. Data can be transported across an MPLS network more efficiently — and with more control — than over a pure IP network.

MPLS takes the non-deterministic nature of IP and enables deterministic control of it. Low latency, for example, is very important for utilities when it comes to the protective switching processes that prevent damage to equipment and injuries to people. IP on its own can't meet the latency requirements for this, but IP over MPLS can.

Maintain reliability for mission-critical applications. MPLS has a traffic engineering capability, enabling the selection of a path across the network that meets specific performance characteristics such as delay and bandwidth. Network resiliency is achieved by means of the end-to-end restoration capabilities that enable the network to reroute connections around a failure in less than 50 milliseconds, which makes it transparent to many applications.

Converge legacy and new communications. Traditionally, each application in a substation was on its own dedicated network. With an IP/MPLS network, numerous applications can run on one shared infrastructure by provisioning virtual private networks, while still guaranteeing the respective quality of service for all individual applications. This means that the most critical applications and lower-priority applications can use the same infrastructure without interfering with each other. The same goes for legacy applications and new ones. IP/MPLS also creates the opportunity to efficiently introduce new applications such as smart meters, sensors and video surveillance that were designed from the start to work on an IP network.

In addition to IP, MPLS can carry TDM, Ethernet and frame relay traffic. This allows utilities to support legacy applications while providing a smooth migration path to IP and Ethernet-based communications. An IP/MPLS network can also be deployed over different types of wireline and wireless media, thus providing a flexible end-to-end resilient infrastructure. This allows utilities to maximize the cost-effectiveness and efficiency of its network without jeopardizing reliability.

IP/MPLS also allows utilities to converge numerous communications systems onto one platform, without having to replicate a network for each application. That substantially lowers the cost of introducing new applications to the network.

Support existing teleprotection. Reliable teleprotection is critical for utilities, as it automatically isolates faults in the grid and keeps people and equipment safe. An IP/MPLS network can support performance requirements needed for teleprotection, including latency. It can smoothly ensure that performance requirements are met for bandwidth, delay and jitter. An IP/MPLS network can also support and preserve the reliability of older teleprotection systems by emulating traditional circuits, and providing traditional interfaces for teleprotection relays. The same IP/MPLS network can also support the deployment of new Ethernet-based or future IEC 61850-based protection relay.

Support existing SCADA. An IP/MPLS network has the flexibility to concurrently support communications for legacy TDM/serial-based SCADA systems and the new Ethernet- or IP-based eSCADA systems (which offer more information and control). This allows utilities to fully leverage their existing assets as they transition to newer systems.

Securing Your Network

Utilities are critical infrastructure, and thus could be more likely than other entities to be targeted by cyberattacks and other security threats. With the smart grid depending on real-time information, the importance of cybersecurity cannot be overstated. And because substations are scattered throughout the service region, often in remote areas, physical security of the electrical grid is another challenge.

The smart grid certainly requires a strong emphasis on cybersecurity. There have been increased efforts from the federal government to further the cause. The North American Electric Reliability Corporation Critical Infrastructure Protection (NERC CIP) regulations are aimed at protecting the reliability of the North American bulk power system. The *National Institute of Standards and Technology Interagency Report (NISTIR) 7628* provides numerous cybersecurity guidelines for the smart grid.

NERC CIP and *NISTIR 7628* are getting much attention from utilities, which aim to observe these standards and make the smart grid as secure as possible. Utilities can be fined up to $1 million per day for violations of NERC CIP regulations. Following are tips for achieving optimum smart grid security.

Create end-to-end security. A smart grid network can contain a core network, field area networks, neighborhood area networks, smart meters, applications, multiple types of technology and much more. Communications running through all of these networks need to be secured end to end. An end-to-end security approach helps utilities protect the rapidly growing number of endpoints on the smart grid. With more endpoints come more security risks. In general, there are many pieces to the smart grid, and taking a comprehensive overall approach is a key part of securing them all.

Assess early and often. Look hard at your entire network, the organization of it, the operational procedures and all other aspects of the network and how it's used. Find the places where there could be security gaps. Assessing the strength of your security system is an important early step, but you also need to realize that security is never finished. It's an ongoing process, and you need to keep re-assessing it periodically. An outside expert may have the best perspective on assessing your smart grid security system.

Create a risk mitigation strategy. Analyze the risks to your smart grid. Understand what will happen if those risks are exploited. Only then can you create a proper risk mitigation strategy. After that, you can begin designing the solution.

Use security by design. When building a smart grid network, keep security in mind from the beginning. The architecture for a smart grid should include security measures throughout. Security features should be embedded in the network. Find the right balance between security, business objectives and network performance. For example, if the encryption method that's being used is causing too much latency in communications, you've secured the data but you've decreased the ability for applications to respond in the proper amount of time. That can cause significant issues with control applications. Sometimes it's beneficial to bring in an outside expert who can help you with network security design.

Ensure availability. More than in a typical enterprise network, availability is of paramount importance for utilities. Citizens, businesses and governments count on electricity being available for their use at all times. Communications for mission-critical applications must be ongoing and trouble free. Thus security needs to be designed so there is no single point of failure. There must be redundancies built into security. If there is a single point of failure, attackers will find it and could bring everything down. Ensuring availability also means having automatic failover capability. Maintaining continuity of communications throughout the smart grid is crucial.

Isolate traffic. As you converge multiple types of traffic over a common infrastructure, it is still important to virtually separate different types of traffic in order to manage security, availability and reliability on a per-applications basis. MPLS allows for numerous virtual private networks (VPNs) — which make it easier to isolate specific traffic from other traffic. With MPLS, you can stack multiple VPNs that provide point-to-point, virtual Local Area Network, and IP VPNs on the same infrastructure. You may have a VPN for security cameras at substations, another VPN to get SCADA to a control center, and so on. Isolating traffic helps protect the privacy and integrity of data.

Know who is on the network. Utilities really need to know who's on the network and what they're doing. The ability to authenticate users' identities is very important to keep unwanted devices and users off your network. Authorizing which information is accessible and what actions a user can take are crucial. Audit trails are also a must.

Protect privacy. It's very important for utilities to carefully protect the data they collect from consumers. Thieves, for example, could learn when people are not at home if they gain access to consumers' energy usage records. Customers need to know that their private information is safe.

Encrypt your data. You don't want cybercriminals intercepting or altering your data. Encrypting data is something that many utilities are considering. Much security is in place to keep cybercriminals out, but if they do get in, you don't want them to be able to see your data. Of course the impact on latency and cost should be considered when evaluating data encryption for a specific application.

Control access to the network. Points at which different physical and virtual networks connect need to be protected to ensure that unwanted traffic cannot cross from one network or VPN to another. For example, if a substation has a VPN for control applications, a backup link via a service provider, a local area network and an Internet connection, a firewall can be deployed to block any unwanted traffic from entering a network. Regulate who can and cannot have access to network services based on the user's role. For example, a finance employee shouldn't be allowed into systems that control the grid. Network Access Control (NAC) solutions simplify the management of role-based access.

Detect suspicious behavior, viruses and other threats. The smart grid is like other IT systems, in that it needs to be protected against viruses, malware and other cyberthreats. Deploy Intrusion Detection Systems (IDS) to detect and report malware activity based on anomalous activity or behavioral signatures that are recognized as attack patterns. Intrusion Protection Systems (IPS) react to the threat and automatically attempt to contain it by blocking ports, changing firewall policies, altering packet content or other mechanisms. IDS, IPS and firewall capabilities can be combined into a single device, called Unified Threat Management (UTM). Utilities should look for IDS/IPS solutions that include support for control protocol-specific signatures.

Consider physical security. Utilities can also leverage communications technology to protect their physical facilities and assets. Remote substations, for example, can have surveillance video cameras on site, sending images in real time to control centers. Analytic software can "watch" the video so humans don't need to, sending alerts when something out of the ordinary is happening.

Due to their remote locations, substations have been the targets of theft, vandalism or other crimes — sometimes without anyone noticing for days or weeks. Copper theft has been a real problem in some areas. Cameras can help with this — and they also can enhance employee safety at substations.

Substandard security at substations could be an invitation for cybercriminals to use them as an entry point for hacking into the grid's electronic systems. Access control, perimeter intrusion detection and video surveillance can all help protect facilities from security breaches, vandalism and theft.

Managing Your Network

Whether you're managing your smart grid yourself, or using a managed services provider to do it for you, you'll want to understand the elements involved in managing the key applications, equipment and processes. Be sure you have an end-to-end understanding of how things work together. That means having a good take on the applications layer, the communications layer and the devices as well.

Following are tips for managing your network. While some of these practices apply more to a utility managing a network on its own, and others relate to a utility using managed services from an outside provider, there is much overlap. If you're using managed services, you'll want to make sure your provider is observing best practices.

MANAGING INTERDEPENDENCIES IN THE SMART GRID

Study the interdependencies. It's extremely important to understand the many interdependencies that are part of the smart grid. Without this understanding, there's a real risk to the success of the smart grid. With the smart grid, there will be many more devices to manage. There is much greater complexity. Many more technologies are involved, from the core network all the way out to the homes of customers.

A typical smart grid could include a core network, field area networks, WiMAX, wireless mesh, PLC, smart meters, collector points, substation automation, applications, control devices and much more. To truly manage the smart grid, you have to understand the interdependencies among all of the different components — and you have to manage those interdependencies.

For example, if a fiber is cut somewhere in the system, it could generate hundreds of alarms, because there could be many devices dependent on that piece of fiber. Your system needs to be able to correlate the alarms, and understand the interdependencies, in order to find the location of the problem. Without knowledge of the interdependencies, it could take much longer to determine the root cause. Being able to find and fix problems more quickly makes the smart grid more reliable.

Use an Operations Support System (OSS). OSS technology provides crucial visibility into — and control of — the smart grid. It supports the monitoring of the different kinds of devices in the smart grid — with support for multiple kinds of technologies and multiple vendors' equipment. Since OSS technology was originally developed for telecommunication service providers, utilities need to choose a solution that takes into account the specific requirements of utility applications.

OSS provides a one-stop view for management of the communication networks and applications within the smart grid. It significantly reduces the time needed to identify, classify and resolve issues. It improves operational efficiency without the need to add employees. It simplifies the management of numerous complex systems. It also makes it easier for the utility to adapt to new technologies and changing business requirements. OSS can also help ensure that services are rolled out in a consistent way, following policies the utility has set. Finally, OSS can reduce errors in provisioning.

Ensure operational procedures. OSS makes sure operational procedures are consistently being followed. For example, NERC CIP has a requirement that says any changes made to a critical cyberasset must be tested beforehand to ensure that the change won't alter the security posture of the device. Before any change is made, you can model the process with OSS tools. You run the tests, and then the change can be approved if all looks good. With OSS you can capture that approval, in case you need it later for an audit.

AUTOMATION AND ANALYTICS

Analysis of how the network is performing is a big part of running a smart grid successfully. Today's technologies offer a great opportunity for network managers to see exactly what's going on within the network. Various smart grid devices are capable of reporting on their status and providing performance statistics. Automatic collection and analysis of this data can significantly reduce the time it takes to identify, classify and fix problems related to the delivery of smart grid services. For humans to sift through the information and find some meaning in it would take much too long. With automated processes, smart grid operators can spend much more time solving issues and much less time searching for the cause.

Automation and analytics can help fix problems, but they can also gather valuable data that helps utilities improve their networks. This data can be used to improve network design, or to help determine how best to add certain applications.

Correlate the data. Your system must be able to collect data from a variety of sources, correlate it all and identify the root cause of any problems. For example, a broken switch at a substation would generate alerts from numerous places in the network. The smart meters themselves could send alerts because they're having problems communicating. The AMI head-ends could send alerts, because they're not getting meter readings. Other devices along the path could also send alerts, in response to that one failed device.

With this data coming in from different systems, it takes solid correlation to recognize this as a single problem — and to understand the relationship among the parts. Correlation software can organize the pertinent data, so it can be quickly analyzed and understood. That leads to the root cause of the problem.

REAL-TIME DECISION-MAKING

The correlation process greatly enables real-time decision-making. Once you've been able to correlate the information from various sources regarding a problem, and have learned about the root cause, you can look at the data in a meaningful way and know what to do about the issue. If the problem is a switch at a substation, for example, you can quickly know whether the best action is to correct it remotely, or send a person to the site to make a repair. Because you have a breadth of data, you can even send the person who has the right skill set for the job.

If a transformer needs to be replaced, having more information about the surrounding neighborhood can be very beneficial. By knowing exactly how many homes are involved and other local usage data, a manager can decide when to disconnect power so as to affect as few customers as possible.

Even without a problem, there are often decisions to make that can be aided by having the kind of detailed data that the smart grid provides. Operations decisions can be based on real-time data on performance in various parts of the network. Almost any decision will be more solid if it's based on comprehensive, real-time information.

MANAGING APPLICATIONS

Managing smart grid applications is an important part of managing the network. But smart grid applications don't exist in a vacuum. They're tied closely into the communications network, so properly managing applications takes an awareness of how things work together.

Network management needs to address communications, the devices involved in those communications and the applications that make things happen. These all affect each other, so you have to look at how they all fit together.

Managing a microwave radio network, for example, involves not just that network, but also the applications running over it, such as distribution automation or substation automation applications. Without a full end-to-end understanding of these applications and the network, and the devices involved, you can have blind spots and problems can arise. Different departments may point fingers because no one can pinpoint exactly where the problem resides.

If there's a failure with meter readings, for example, is it because of the network? Or is it due to a certain part of the network? Or is it with the smart meter application itself? Managing the applications requires understanding the applications and everything around them.

AUTOMATED MANAGEMENT OF ASSETS IN THE FIELD

Managing network assets is more important than ever before as new devices such as smart meters and collector points are added to the network. Federal government reporting guidelines are making it desirable for utilities to have solid inventory management systems for smart grid devices. Utilities need clear visibility to these assets. Additionally, it can be difficult to inventory legacy assets that were put in place long before asset management became such a priority.

With modern asset inventories, utilities will have more information about their assets, which they can use to help with some of the advanced management techniques that come with OSS. The information can help managers understand the relationships among devices. This can help tremendously with root cause analysis when issues arise. Automated management processes will work better with accurate information in the system regarding all assets.

Make better decisions. Strong asset management will help managers make good decisions about what equipment to upgrade, and when. When should an item be replaced? What is it connected to? What happens if it fails? Knowing as much as possible about each asset helps managers make better decisions.

When a device fails, having the proper data can help determine quickly the best way to repair or replace that device. It's much better to know the information before a decision is made than to discover the information later, when you're in the middle of trying to fix the problem. It's better to know you can update or fix it remotely than to send a truck when you don't need to.

Get the details. Collect and track as much information as possible, including important items such as serial number, IP address, software release, maintenance history and planned maintenance.

DEPLOY DEVICES AND KEEP THINGS RUNNING

Moving to the smart grid requires adding huge numbers of new devices to the network. While you need to ensure that devices already on the network continue to run smoothly, you'll also want to make sure all the new devices are working as well as they should.

Deployment should include a process that captures information about the devices as they're being installed in the field. There are several ways to do this, including having personnel enter the information via a Web portal, using a bar code scan or RFID tag, or having auto-discovery mechanisms in your inventory and asset management systems. Once the data on the new assets has been added to the system, the assets can be closely managed with end-to-end OSS.

If you're using a managed services provider to manage your network, that provider can probably also help in deployment and organization of the thousands of new endpoints. The provider should have a network operations center that can coordinate a significant amount of the activity around deploying the smart grid devices. For example, for every smart meter that's deployed, the provider can immediately make sure the data flows from the meter, through the collector point, back through the communications infrastructure and to the proper application. The provider can also immediately verify that the meter is working correctly. It's much more efficient than to have a field crew install the meters, then go back out to the sites later to make sure the meters are working properly.

KEYS TO SUCCESSFUL OSS DEPLOYMENT

Utilities are most likely to succeed with an OSS by engaging a partner that can provide them with the required level of expertise. IT expertise is not enough. Telecom expertise is not enough. Expertise in a given application is not enough. To successfully deploy an end-to-end OSS solution, utilities require a partner that can thoroughly understand the business drivers, the processes, the modern Web services-based architectures, the legacy and next-generation equipment, IT and telecom and the utility environment.

A fully realized OSS ecosystem is likely to require products from multiple vendors. Having a single OSS integrator responsible for the project greatly reduces the utility's risk and increases the likelihood of a successful deployment. The OSS integrator should demonstrate a proven, disciplined methodology for achieving OSS success.

It's also critical to get the stakeholders from multiple organizations within the utility to sponsor and align on the project. Training has to be a part of the solution, for both the applications and the processes, to ensure that individuals are leveraging the OSS to fully harness the control it provides for creating, delivering and assuring the utility's network services.

How can a utility get started? Should it focus on one or two critical systems, such as inventory management, or network-wide fault management? What is the end goal, and should there be a phased approach? Does each subsequent phase depend on the success of the previous one, and how is success measured? All of these things need to be considered to determine the path to an integrated system. The right OSS integration partner can help the utility analyze its present mode of operations and come up with a plan to achieve the desired future mode of operations.

Realizing Green Energy

The smart grid is more efficient than the traditional grid. It improves operations and helps consumers use less energy. Throughout the smart grid, new efficiencies result in smaller impacts on the environment. Creating a smart grid is one of the most environmentally conscious actions a utility can take. The smart grid takes a giant system and makes every piece of it more focused on productivity and less likely to waste anything.

Maximize consolidation. By consolidating your communications network infrastructure, you need less equipment, fewer truck rolls for repairs and less power to run everything. You can also consolidate applications, servers and data centers. Avoiding duplication of infrastructure means making less of an impact on the environment.

Make real-time decisions. The smart grid gathers an enormous amount of data about network operations and the delivery of power to consumers. The ability to process this data helps utility managers make better decisions on how to generate and deliver energy in the most efficient manner possible. It creates a more efficient grid, which is a greener grid.

Support renewable energy. Green energy sources can be everywhere — homeowners with solar panels, wind turbines in remote places and waves from the ocean are just a few. By incorporating these and other renewable energy sources into the smart grid, utilities can reduce the overall level of energy they must generate themselves. But utilities need to closely monitor and control these new resources' impact on power quality and grid stability. Without secure, reliable communications in real time, there is a risk of de-stabilizing the grid.

Store energy. Historically, energy has been produced and consumed at the same rate. Storage hasn't been a practical solution, but today, there is much research and development devoted to energy storage systems. For example, electric vehicle batteries, hydro and thermal can all store excess energy and give it back to the grid. Storage capabilities will be essential if utilities are to take full advantage of renewable energy resources, such as wind and solar. With smart grid communication networks, utilities can monitor energy storage facilities, pinpoint sources of energy closest to demand and pull energy from those resources when needed. This will enable utilities to reduce their reliance on peaking plants and leverage greener sources of energy.

Deploying Your Network

When it's time to deploy smart meters, substation automation and other aspects of the smart grid, many utilities work with an experienced network integrator to ensure that this very important process goes smoothly. Whether a utility does that or not, there are several tips to keep in mind.

See the network as a whole. As with planning and design, you need to look at your smart grid network as a whole entity, not as individual components. How do your systems interoperate with each other? How does data travel across the network? The overall network is made up of smaller networks and other components. Make sure you understand how the pieces must come together in the deployment phase.

Understand interaction between networks. In the smart grid, data travels from neighborhood networks to FANs to, most likely, an MPLS core network. The intersection points between these networks are critical; it's where information from one type of technology is handed off to another. You typically have different technologies, plus different vendors with different ways of interpreting standards — all of which make it more complex than smaller networks built for one purpose. In the smart grid, it's extremely important to be certain these interactions are working properly.

Do interoperability testing. With all of the technologies involved, you must make sure ahead of time that they're going to work well together. Interoperability is crucial. Things must work together seamlessly. Testing is important not only during the design phase, but also during deployment. You don't want to be dropping data packets at gateways between technologies.

When working with a network integrator, you should get solutions that have been pre-integrated, meaning interoperability is assured because it's already been tested by the integrator. The interoperability should be guaranteed.

Engage a network integrator. Rather than adding numerous vendors as needed, it might be best to work with a network integrator. That integrator should be able to look at the entirety of what should be deployed across everything, setting things up as a whole. An experienced network integrator knows how to get the most efficiency and quality out of a smart grid deployment. It's important to choose an integrator with experience all the way through the communications infrastructure, from the edge, through the FAN, and all the way back to the core network and into the applications. Utilities don't typically have this kind of communications experience, so it can be very beneficial to work with a network integrator.

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