TEN STEPS TO A SMARTER GRID

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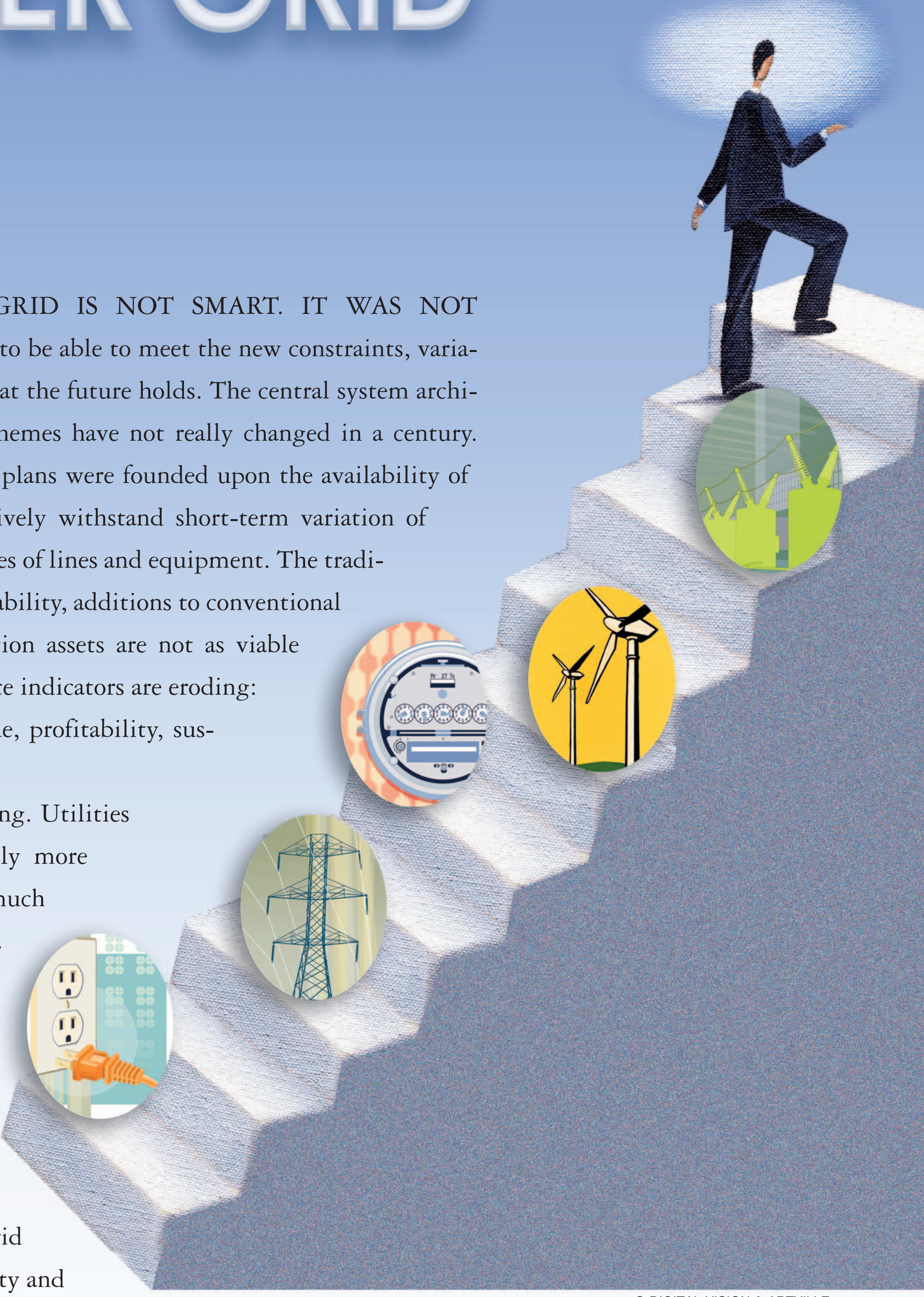

THE U.S. ELECTRIC GRID IS NOT SMART. IT WAS NOT planned and constructed to be able to meet the new constraints, variables, and uncertainties that the future holds. The central system architecture and operating schemes have not really changed in a century. Long-term construction and operations plans were founded upon the availability of extra capacity and redundancy to passively withstand short-term variation of demand, longer term growth, and outages of lines and equipment. The traditional tools to achieve adequacy and reliability, additions to conventional generation, transmission, and distribution assets are not as viable now. Already, electric utility performance indicators are eroding: economy, reliability, security, asset value, profitability, sustainability, and service quality.

Things will get even more challenging. Utilities will have to operate under considerably more complexity and uncertainty as well as much closer to the margin in days to come. They will have to deploy and utilize better ways for real-time monitoring and control of their existing facilities as well as ways for consumers to do the same. A modern utility will have to accommodate national and regional grid interruptions, volatility in the availability and

The concept of an intelligent electric utility infrastructure

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price of fuel, increased deployment of distributed generation and storage, increased consumer involvement, retail premises automation, and 24/7/365 online service and commerce.

To accomplish this, electric utilities are going to have to expand monitoring and control throughout their distribution grids all the way to the customer's side of the meter. Fortunately, new and emerging technologies will make this possible. In fact, new electronics, telecommunications, and information technologies will allow electric utilities to achieve unprecedented efficiency, economy, quality of service, safety, security, sustainability, and flexibility.

AN ELECTRIC UTILITY POWER SYSTEM TODAY LOOKS MUCH LIKE IT DID MORE THAN 100 YEARS AGO.

This article includes a ten-step plan for electric utilities to make their distribution grid a modern, smart, and an agile one. This plan is presented in the form of a smart grid audit that can be used continuously to assess and deploy practical options to make the grid smarter.

If I Only Had a Brain

The Electric Utility Grid Is Not Smart

An electric utility power system today looks much like it did more than 100 years ago. For the most part, they are still planned, constructed, and operated with the same theories, topologies, technologies, and tactics. In fact, some of the key technologies such as the electromechanical meter are more than 100 years old.

Electric utilities continue their traditional approach for maintaining adequacy, reliability, and quality of service by planning and constructing generation, transmission, and distribution with enough extra capacity and redundancy to accommodate possible changes in customer demand and recover from facilities outages. The only real option that utilities have at their disposal to significantly reduce the likelihood and duration of service degradation or interruptions is to add generation, transmission, and distribution facilities. Once constructed, there are few options open to an electric utility to control or manage the system other than matching generation to consumption. In fact, a key principle of operations is to interrupt the service provided to customers to protect utility assets from damage.

Unfortunately, the business environment in which electric utilities must operate has not remained similarly unchanged. The new environment demands a different approach for planning and operations.

A New Operating Environment

The environment in which utilities operate has changed drastically and is expected to continue to do so. And that is not just a pun on climate change. One does not have to look far or ponder much to see that a new future looms.

In January 2009, the United States Department of Energy (U.S. DOE) released an assessment of the U.S. electric grid based on the work of its Electricity Advisory Committee (EAC). Known as the electricity adequacy report and officially titled "Keeping the Lights On in a New World," [1] the report paints a dismal picture of a grid that is neither modern nor smart. Specifically, the report states:

> Much of the electricity supply and delivery infrastructure is nearing the end of its useful life.

Read this report as well as the many other sources on the smart grid and you will find:

1) increasingly frequent regional bulk power system outages and projected continued decline in reliability of the bulk power system
2) increasingly unacceptable environmental impact
3) rising risk in planning, construction, and operation of electric utility infrastructure:
   a) fuel supply constraints and uncertainties
   b) rising magnitude and volatility of costs and prices for raw materials and finished goods
   c) financial instability
   d) global industrial development and competition
   e) complex new operating conditions and
   f) post 9/11 national security concerns
4) rising customer expectations with regard to the reliability, quality, and economy of their electric utility service.

A Smart Grid Is Desirable and Possible

The good news is that there is good news. While the aforementioned adequacy report was released, the U.S. DOE released its final smart-grid report, also the work of the EAC. The report titled "Smart Grid: Enabler of the New Energy Economy" [2] substantiates

> the benefits of moving to a more intelligent grid, not only for utilities and grid operators but also for consumers and society as a whole. Studies have shown that the potential economic and environmental payoffs of transforming the current electric power delivery system into a smart grid are numerous. From an economic perspective, a smart grid can enable reduced overall energy consumption through consumer education and participation in energy efficiency and demand response/load management programs. Shifting electricity usage to less expensive off-peak hours can allow for better utilization of equipment and better use of capacity. From an environmental standpoint, a smart grid can reduce carbon emissions by maximizing demand response/load management, minimizing use of peak generation, and replacing traditional forms of generation with renewable sources of generation. A smart grid also holds the promise of enhanced reliability and security of the nation's power system.

Among other things, the report recommends:

> establishing a coordinated strategy that capitalizes on using smarter technology to evolve to a smart grid.

Off to See the Wizard

Here is the problem with the smart grid. Nobody knows exactly what it is. Pretty much everybody agrees that we need it for various reasons and to varying degrees. A vision of the smart grid is presented by the U.S. DOE's National Energy Technology Laboratory in "A Vision for the Modern Grid" [3].

- *Self-heals*: Today's grid responds to prevent further damage. Focus is on protection of assets following system faults. The modern grid automatically detects and responds to actual and emerging transmission and distribution problems. Focus is on prevention. Minimizes consumer impact.
- *Motivates and includes the consumer*: Today's grid consumers are uninformed and nonparticipative with the power system, whereas in the modern grid, they are informed, involved, and active. Broad penetration of demand response.
- *Resists attack*: Today's grid is vulnerable to malicious acts of terror and natural disasters, whereas the modern grid is resilient to attack and natural disasters with rapid restoration capabilities.
- *Provides power quality (PQ) for 21st century needs*: Today's grid is focused on outages rather than PQ problems. Slow response in resolving PQ issues, whereas in the modern grid, the quality of power meets industry standards and consumer needs. PQ issues identified and resolved before manifestation. Various levels of PQ at various prices.
- *Accommodates all generation and storage options*: Today's grid has a relatively small number of large generating plants. Numerous obstacles exist for interconnecting DER. The modern grid has very large numbers of diverse distributed generation and storage devices deployed to complement the large generating plants. Plug-and-play convenience. Significantly more focus on and access to renewables.
- *Enables markets*: Today's grid has limited wholesale markets still working to find the best operating models. Not well integrated with each other. Transmission congestion separates buyers and sellers. The modern grid has mature wholesale market operations in place; well-integrated nationwide and integrated with reliability coordinators. Retail markets flourishing where appropriate. Minimal transmission congestion and constraints.
- *Optimizes assets and operates efficiently*: Today's grid has minimal integration of limited operational data with asset management processes and technologies. Siloed business processes. Time-based maintenance. The modern grid has greatly expanded the sensing and measurement of grid conditions. Grid technologies deeply integrated with asset management processes to most effectively manage assets and costs. Condition-based maintenance.

Obviously, this is a dramatic departure from the legacy electric grid. It involves grand visions and bold strategies with few specifics on how they will be implemented. It would need a wizard to conjure it up.

A KEY PRINCIPLE OF OPERATIONS IS TO INTERRUPT THE SERVICE PROVIDED TO CUSTOMERS TO PROTECT UTILITY ASSETS FROM DAMAGE.

On the other hand, the predominant vision of the incumbent electric utility industry seems to be to get back to the straightforward, cost-plus monopoly arrangement and build more conventional transmission and generation. This is equally impractical. It would also require a wizard to make it happen.

There will be no return to the simplicity of the 20th century regulatory compact or the central station electric utility model. The future is not like the past for all the reasons set forth in the U.S. DOE electricity adequacy report. It is obvious that electric utilities are going to have to change how the grid is planned, constructed, and operated. It is just not clear how. Because the future is unpredictable and uncertain, the industry will have to innovate and improvise to make it happen.

Steve Hadden, vice president of Plexus Research, and Shannon Messer, senior consultant at R.W. Beck, note this in a series of articles for T&D Automation, "A Useful Thing Happened on the Way to the Smart Grid: The Agile Grid" [4] (Parts 1, 2, and 3). They state:

> The concept of an intelligent electric utility infrastructure or smart grid is attracting wide interest among utilities, consultants, regulators, and other utility stakeholders. This interest, however, is accompanied by widely differing expectations about when smart grid will emerge. Some confidently proclaim that the smart grid is here or just around the corner. But utility management and staff responsible for operating real electric systems are understandably cautious. They realize that smart grid will not suddenly become available in a suite of closely bundled technologies and applications. And they are pragmatic about the technology needed today to improve distribution operations for the next few years.

Fortunately, this is doable without a wizard. Many utilities have already made a good start on a more intelligent grid. Hadden and Messer go on to say:

> The concept of intelligent infrastructure will continue to evolve, but utilities have tangible choices now, and they do not have to wait passively to provide practical solutions as smart grid develops. Utilities can begin using existing and emerging technologies and applications to create something we call an agile grid, on the way to creating a smart grid. Many utilities already have deployed, or are planning, key elements or components of an agile grid.

What Is Behind the Curtain?

So what is the reality of the smart grid once one gets past the pyrotechnics? It is making the grid smarter a little bit at a time. Just as the band America sang, "Oz never did give nothing to the tin man that he didn't, didn't already have," the industry is going to have to educate itself. It will do this by continuing to deploy three fundamental building blocks: distributed intelligence, digital communications, and decision software.

> THE BUSINESS ENVIRONMENT IN WHICH ELECTRIC UTILITIES MUST OPERATE HAS NOT REMAINED SIMILARLY UNCHANGED.

Distributed Intelligence

The smart grid has a lot to do with decentralization: distributed generation and storage, distribution system automation and optimization, customer involvement and interaction, plug-in hybrid electric vehicles, and even micrograds. That means that it will be necessary to have more intelligence and control beyond generation and transmission throughout the distribution grid and all the way to the retail consumer's side of the meter.

This will involve both fixed and mobile devices. Fixed devices will include:

- supervisory control and data acquisition (SCADA) devices and distribution automation (DA) devices
- automatic meter reading (AMR) devices and smart meters
- retail premises monitoring and control systems and energy management systems (EMSs)
- emerging technologies for monitoring and control, both for electric utilities and consumers.

Mobile devices will include:

- voice and data dispatch radios
- geographic positioning system devices
- automatic vehicle location devices
- mobile computing devices (e.g., laptop PCs and personal digital assistants)
- cell phones and other mobile communications and Web-access devices.

Digital Communications

Remote monitoring and control devices require two-way communications. And, since the smart grid is, by definition, about real-time data and active grid management, fast, digital, two-way communications will be required throughout the smart grid. It will be required between and among the electric utility, the meter, the utility's and consumer's devices. In all likelihood, two-way digital communications will be required with third-party entities, too. For example, in Texas, there is a network of nonutility reps and resellers who are active in the competitive retail market. They are involved in metering and billing as well as matching resources and load. In the future, there may be other technologies available from third-party vendors to track usage, environmental impact, and costs by individual appliance in the consumer's home or office.

Electric utilities already use a wide variety of digital telecommunications, including:

- wired and wireless telephone
- voice and data dispatch radio
- fiber optics
- power line carrier
- satellite
- the Internet:
  - fiber
  - hybrid fiber cable
  - digital subscriber line
  - broadband over power lines
  - wireless fidelity and worldwide interoperability for microwave access
  - satellite.

Electric utilities make use of both wholly owned and operated networks and third-party networks.

Decision and Control Software

One of the problems that utilities had with the precursors of the smart grid and the first and second generations of SCADA and AMR was making effective use of the available data. In the smart grid, this will involve way more than a monthly or daily meter reading and notifications of outages. It will involve dynamic grid management based on real-time state estimation. This means monitoring, analyzing, and managing a staggering number of monitoring and control points.

The new world of electric utility operations will require the monitoring and control of every power line and piece of equipment on the distribution system. It will also involve an increased level of monitoring and control for every one of the utility's retail consumers. Meaningful involvement by the retail consumer will likely involve multiple monitoring and control devices on the consumer's premises. Immense amounts of data will have to be organized, analyzed, and acted upon. Extremely large numbers of control points will have to be managed. That is going to require decision software. This software will come in two basic categories, decentralized and back office.

Decentralized Software

The magnitude of the devices and data will preclude centralized data collection and computation. Instead, the devices will increasingly be intelligent electronic devices (IEDs) that can collect, organize, and analyze data as well as perform computations to determine what data should be communicated back to the utility or to the consumer and what immediate local control actions may be necessary. This will be firmware built into the devices as well as downloadable, programmable software.

For example, a smart meter might have firmware to monitor and record certain variables such as voltage, current, power factor, and to compute kilowatt and kilowatthour. It might also have programmable capabilities to determine if and when to report variables outside certain ranges and/or to control local devices.

Back-Office Software

Most utilities already utilize some of the following back-office software:

- Enterprise Resource Planning
  - Accounting and Business Systems
  - Customer Information Systems (CIS)

- Customer Billing and Payment
- Customer Relationship Management (CRM)
- Work and Workforce Management
- Performance and Productivity Management
- Engineering and Operations
  - Engineering Analysis
    - Circuit Modeling and Analysis
      - Reliability Analysis
      - Real-Time Distribution Analysis
  - Outage Management System
  - Active Distribution Grid Management
- Geographic Information Systems (GIS)
- Interactive Voice Response (IVR).

THE U.S. DOE RELEASED AN ASSESSMENT OF THE U.S. ELECTRIC GRID BASED ON THE WORK OF ITS ELECTRICITY ADVISORY COMMITTEE.

Each and every one of these back-office software solutions becomes more powerful and effective by the deployment of IEDs and two-way digital communications.

Flying Monkeys

Unfortunately, there will be a huge problem. Deploying distributed intelligence, two-way digital telecommunications, and decision software will quickly reveal that they are not interoperable. Brand A does not always (if ever!) work with Brand B. In fact, Brand A does not always work with Brand A. Every attempt to implement another piece of the smart grid puzzle is plagued by difficulty. How are utilities and their customers going to be able to monitor and control successfully in real time if all the systems do not interoperate seamlessly?

Utilities take various approaches to this problem:

- *One stop, one shop*: Obtain a complete, turn-key solution from a single vendor. Unfortunately, there is no such solution and no such vendor just like there is no wizard and never will be. By taking this approach, a utility will have to forgo some smart grid functions and features. And, the utility will have to accept less than the best in some or many parts of the system that are available depending on the competencies and capabilities of the vendor. This gets worse as the three basic categories are mixed. For example, it is very unlikely that the best SCADA vendor is going to have an equally great CIS. Or that an acceptable telecommunications network provider will have either CIS or SCADA. Even within a category, such as decision software, a best of breed CIS vendor is not necessarily going to field an equally good real-time distribution state-estimation solution.
- *Vendor to vendor cooperation*: A utility may approach this in a couple of different ways. One is to buy only from vendors who have already demonstrated integration with each other. Another is to require vendors (i.e., through an request for proposal or bid process) to agree to integrate to be selected. Relying on vendor cooperation can work, but it will significantly reduce the field of vendors that a utility will be able to deal with. It can also cause added expense and delays.
- *Industry standards*: This is really a variation of vendor cooperation. It just becomes so pervasive that only the cooperating vendors can hope to survive. One example of this is Transfer Control Protocol/IP. If you want to communicate over the Internet, you make use of this protocol. It does not matter what kind of information you are exchanging or over what telecommunications medium. Whatever brand of computer or phone or modem or software that you buy, it is going to fit this standard. However, it is initially very difficult to achieve industry standards in an emerging market where 1) everyone is hoping to take the market by storm and therefore have no interest in being easy to integrate (i.e., easy to replace) and 2) most of the market entrants are entrepreneurs and startups with limited capital and resources to build to an industry standard before launching a product.
- *System integrators*: Retain one or more experts to create the necessary interfaces between and among the various vendors. This can be helpful, but it can also be extremely expensive and time consuming. And it never ends. Every time a vendor has to be replaced or a vendor issues a new release or a new vendor is added, more integration is required.
- *Service-oriented architecture (SOA)*: This is the ultimate system integration. It involves a universal Web services based data bus architecture that allows dynamic data exchange with each vendor independently. This would obviously be preferable to trying to integrate many vendors with each other directly. Unfortunately, it still requires the Wizard because it depends on the vendors' cooperation in integrating with the SOA, the continued development and maintenance of the SOA to accommodate necessary features and functionality, and the involvement of a system integrator. It also requires the continued development and maintenance of the SOA over time.
- *Brute force*: Just learn to live with the monkeys. Allow the smart grid to be mean, uncooperative, and messy.

The Wicked Witch Is Dead

There is an excellent emerging solution to the flying monkey problem. Some years ago, the National Rural Electric Cooperative Association's Cooperative Research Network undertook to create a voluntary data exchange standard that would eliminate some if not all of the flying monkeys. This initiative, known as MultiSpeak [5], has matured into a standards-based, Web services SOA. It has been joined by a large number of vendors in all three smart grid categories, and more are joining every day. While not universally adopted, nor yet exhaustive in function and feature, it is the best available combination of vendor cooperation, industry standards, and SOA. If electric utilities unite in requiring vendors in all three categories to program to this industry standard SOA, then not only will the flying monkeys be gone, the witch will be dead.

THE MODERN GRID AUTOMATICALLY DETECTS AND RESPONDS TO ACTUAL AND EMERGING TRANSMISSION AND DISTRIBUTION PROBLEMS.

Click Your Heels

There is no point in trying to find the Wizard. He can't help. We might as well go home. Even if home is a bit of a mess.

The tin man found out as he made the journey to Oz that he did have a brain, he just had to use it. Many electric utilities have made a good start. Here is a plan for an electric utility to get started and advance. Actually, it is more of a tour guide because the destination, the future, is always changing. It is a simple, ten-question audit. Do it now. Repeat it every few months. The goal should be to be able to show progress in every area.

1) Is there at least one senior professional in your organization who is responsible to stay informed about smart grid developments, technologies, deployments, and results as well as ensuring that your utility moves forward in this area?

   If you don't have somebody that is qualified in charge of this critical matter, you will not keep up.

   (Once you are able to mark this item complete, then replace it with this question: Is your progress in making your grid smarter as much a part of your performance measurement and management as your financial statements for your staff, your executive team, and your board of directors?)

2) Can you do all of the business that your customers wish to transact with you whenever (i.e., 24/7/365) and by whatever means (e.g., in person, by mail, on the phone, via the Web, and on their mobile handheld device) that they wish to do so?

   In other words, can you do business with your customers as well as Amazon, or Federal Express or their mobile phone provider? Hint: You can't if you don't have CIS/CRM. You can't if you don't have IVR. You can't if you don't have Web commerce.

   [Once you are able to mark this item complete, replace it with this question: Do your business systems automatically recognize your customer upon contact (without having to ask for their account number) and instantaneously retrieve and present their pertinent data?]

3) Is it possible for you and your customer to know at any time what the services that they are getting from you are costing them, in terms that they can readily understand, as well as how much the cumulative cost right up to the minute since the last time they checked on it or got a bill?

   If they have no idea the rate at which they are spending, or the total amount that they have spent so far, if they cannot find out until weeks or months later when you have read their meter and rendered a bill, and if you provide them with a bill that they do not understand, then they cannot make timely, rational, consistent decisions to manage their consumption and costs.

   [Once you are able to mark this item complete, ask the same question but instead of being able to simply and effectively communicate the cost of service, instead choose environmental impact (e.g., carbon footprint and the portion of their consumption that came from renewable energy sources).]

4) Have you provided your consumers with convenient monitoring and control technologies to enable them to manage their energy consumption, costs, and impacts?

   It is highly unlikely that most consumers, even if they could understand their cost of energy or environmental impact, will be able to effectively manage their energy usage. It involves too many variables that will change to frequently, and they don't have the tools to do so. They are going to have to have automated EMSs. This should be the priority when you make your decisions in the not too distant future about deploying third-generation smart meters.

   [Once you are able to mark this item complete, replace it with this question: Are you providing your consumers with price or other data that allows them to manage their energy consumption in a way that achieves their goals (e.g., cost, environmental impact, and sustainability)?]

5) Do you have a complete, accurate circuit model of your distribution system detailed all the way to the individual retail customer, and are you using it effectively for planning, analysis and operations?

   How can you possibly expect to have a smart grid if you are not as smart about your grid as you can possibly be? The best possible automated outage management is not possible without this. Complete and accurate GIS is not possible without it. Real-time distribution analysis, active grid management, and feeder optimization cannot be done without it.

   (Once you are able to mark this item complete, replace it with this question: Are you making effective use of all of the information available from your SCADA, DA devices, and smart meters along with your detailed circuit model to optimize the operations of your existing distribution system?)

6) Do you have an automated outage management system in place that incorporates the detailed circuit model?

The detailed circuit model is essential to accurately locate and resolve service interruptions, identify and communicate with affected customers, and really understand in detail the reliability metrics for your distribution system. This is mature, proven technology that is already in wide use by electric utilities. If you don't have this in place, you are not taking maximum advantage of existing technology to optimize service to your customers.

[Once you are able to mark this item complete, ask the same question, only replace outages with any service degradation (e.g., voltage regulation, blinks, and harmonics).]

A SMART GRID WILL YIELD GREAT BENEFITS AND IS POSSIBLE WITH EXISTING AND EMERGING TECHNOLOGIES.

7) Do you have a GIS that fully incorporates the connectivity and analysis of the detailed circuit model?

Digital maps with a complete representation of your electric utility assets and customer information as well as the underlying land base are essential for a smarter grid. Furthermore, it is paramount that you maintain with the GIS the complete connectivity and analysis of the electric distribution grid. Pretty much all GIS solutions will geographically map assets and maintain associated attributes. Almost none of them actually model the electrical connectivity or analysis of the electrical distribution grid. You will need both capabilities for a smarter grid.

(Once you are able to mark this item complete, replace it with this question: Does every department and individual in your electric utility, including your customers, have access to the full functionality of the GIS system as necessary or desirable?)

8) Have you deployed SCADA throughout your distribution grid?

A smart grid means that an electric utility can determine in real time the status and characteristics of every component part of the grid and be able to actively manage every controllable device.

[Once you are able to mark this item complete, replace it with this question: Do you have a well defined strategy and plans to migrate to smart metering (i.e., third-generation IEDs, not your father's AMR) for every customer?]

9) Do you have a well-defined strategy and plans to take maximum advantage of the Internet for your smart grid?

Until now, electric utilities have relied upon fielding their own communications systems for voice and data dispatch, SCADA and AMR. Today, a rapidly growing number of industry standard technologies and third-party providers are making it possible to reach customer with high speed, broadband Internet as well as infinitely proliferating applications that can be of use to utilities and their customers. Any electric utility smart-grid strategy must take maximum advantage of this ultimate smart grid.

(Once you are able to mark this item complete, replace it with this question: Can you access and execute all of your smart grid capabilities via the Internet with a remote or mobile device?)

10) Do you have a well-defined strategy and plans to operate "off the grid" for an extended period of time?

Do you have contingency plans for prolonged bulk power system outages? While still not highly likely, the probability of such outages is growing, not declining. To not be planning for this possibility is to not be preparing adequately to serve your customers. And what about your customers, especially large C&I installations, who may want to operate distribution systems off the grid? Will you be able to help them or just lose them? It takes a truly smart grid to be a microgrid and operate reliably for any period of time.

[Once you are able to mark this item complete, replace it with this question: What can we do next with electronics, telecommunications and information technology to substantially improve efficiency, economy, sustainability, environmental impact, reliability and quality of service? (Assign your answer to Question 1 above to carry this forward!)]

There's No Place Like Home

A smart grid is going to be necessary. It will yield great benefits and is possible with existing and emerging technologies. A smart grid will result from a continuous process and not by magic. So, get started now on the process of making your grid smarter.

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