Defining the Smart Grid

Integrating key technology capabilities that enable better business decisions for improved grid reliability and efficiency

Defining the Smart Grid

Introduction

The "Smart Grid" has received much attention in the power and energy industry during the past few years, which has led the media and general public to overuse the term, increasing the ambiguity surrounding what it is. Furthermore, with the smart-grid having been a key part of the American Reinvestment and Recovery Act, many new products for electric utilities or relating to the use of electricity have been casually labeled a Smart Grid solution, further diluting the understanding of the Smart Grid's intended objectives.

So how do utilities cut through the "noise" and define a clear strategy for themselves with technology investments that provide the true capabilities they need to attain a smarter grid? While some utilities have already begun adopting technologies and processes to move toward a smarter grid, many lack a holistic approach, whereby smart grid functions operate as an integrated system, which is a strategic imperative for success.

This paper discusses four Smart Grid functionalities that are critical to helping utilities move toward a modern energy infrastructure, enabling grid optimization and financial sustainability. Readers will understand how a holistic approach that encompasses advanced and integrated software capabilities can provide intelligence for better operational and business decisions—increasing reliability and efficiency.

The Smart Grid is the coupling of electric utility equipment with data communications—an intelligent system that leverages real-time information and analytics—increasing reliability, integrating renewable energy resources, and helping managers make better business decisions.

Why do we need to define the Smart Grid?

According to Paul Feldman, independent participant in the energy industry and Midwest ISO Chairman, U.S. electric utilities spend about $45B on distribution reliability programs per year. Today's existing electric infrastructure is a collection of disparate, aging systems, clearly calling for a more reliable, efficient grid, particularly as the Energy Information Administration expects U.S. loads to increase by 23% over the next 20 years.

The Smart Grid isn't anything completely new; in fact, some aspects have been around for more than 30 years, mostly as individual solutions to specific problems such as having remote control of generating plants and substations.

Today's modernization of the electric utility infrastructure integrates communications with generators, substations, breakers, and meters, with the goals of improving the reliability of the electric system, integrating renewable energy into the power supply mix, and providing information that utilities and customers need to make consistent and informed energy-related business decisions.

To take advantage of true smart grid technology and manage a more intelligent, cost-effective grid, utilities need to develop a holistic plan or "roadmap" that is flexible yet integrated. Having a comprehensive strategy can help utilities minimize the traps and pitfalls of selecting inappropriate or incompatible products and technologies, and ensure that investments truly work toward grid optimization.

A critical factor in managing a more intelligent grid is the need for an open architecture that enables seamless connectivity and interoperability with current and future technologies. Solutions should build on each other without the risks and costs typically associated with integrating disparate technologies. An open architecture protects existing investments that utilities may already have while providing them with the flexibility to scale their smart grid solution over time with additional solutions as resources allow.

The need to define the Smart Grid is driven by the realization that many so-called smart grid products do little to improve reliability, integrate renewable energy resources, or help managers make better business decisions. A holistic roadmap provides a comprehensive plan with technologies and modular steps that build on each other to meet a utility's customized needs.

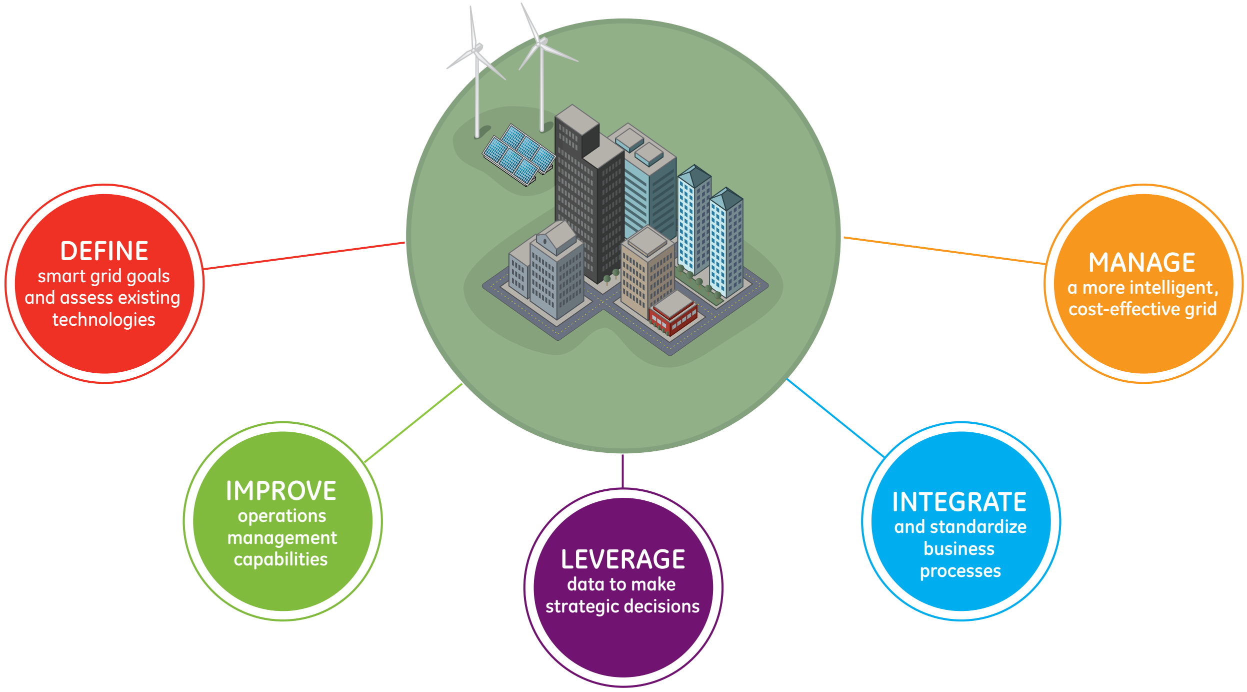


Figure 1 Smart Grid Roadmap

What are the key functionalities of the Smart Grid?

Many utilities today need increased visibility into their operations and the ability to transform data into information for better decision-making and more consistent processes. To capitalize on the promises of the Smart Grid, utilities should evaluate the solutions in their smart grid plans with respect to four critical capabilities:

- Does the solution provide greater visibility and control of the utility distribution system?
- Does the solution provide information to manage the lifecycle of key equipment?
- Does the solution manage customer loads and distributed generation resources?
- Does the solution capture and electronically manage standard operating procedures?

Operations management

Each electric utility has millions of dollars invested into physical plant. Substations, poles, wires, equipment, and generation facilities have significant book value and even higher replacement value. Yet many utilities do not have good visibility into their operations, and still rely on customers to notify them that the power is off at their home or business.

Utilities that serve end users of electricity have indicated that their primary objective is reliability, which can only be achieved with remote monitoring and control of the equipment. If a utility is waiting for the customer to call and indicate that power is out, it needs to start its smart grid journey by implementing operations management capabilities to monitor its facilities.

Software with advanced SCADA capabilities

Visibility into the electric system can help utilities reap huge rewards when coupled with the remote control functions available from a true SCADA software system that enables real-time data collection, dynamic data display, and secure operator supervisory control.

Understanding when equipment is out, dispatching crews to the appropriate areas, and closing breakers remotely without having to send a lineman to the substation can improve some of the most basic key performance indicators of the utility. Specifically, utilities can reduce their CAIDI (customer average interruption duration index) and SAIDI (system average interruption duration index) metrics.

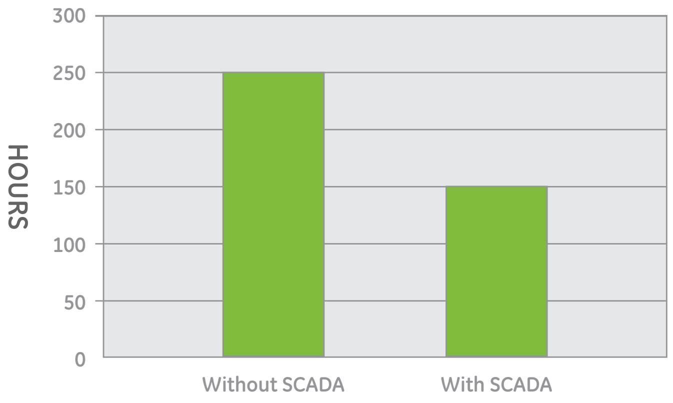
For example, let's say that at 2 a.m. a breaker in the substation opens and 100 customers are out of power; since most customers are asleep at that time, it takes the first customer 30 minutes or more to call to report the outage. It takes the crew 60 minutes to drive to the location, patrol the line, and open a switch between the tree in the line and the substation. The crew will then send a man to the substation to close the breaker, which will take 30 minutes. Once the breaker is closed, 50 of the customers come back online and 50 will remain off for another hour until the lines are repaired. Customer outage time can be calculated as follows:

0.5 hours x 100 customers = 50 customer hours
1 hour x 100 customers = 100 customer hours
0.5 hours x 100 customers = 50 customer hours
1 hour x 50 customers = 50 customer hours
Total customer outage time = 250 customer hours

Let's consider the same scenario with a SCADA system; the system alarm goes off at 2 a.m., and a crew is immediately dispatched. The crew patrols the line and opens the switch in the same one-hour period. SCADA is used to close the substation breaker; it takes the crew the same hour to repair the line and return all customers to service. The calculation for customer outage time is as follows:

1 hour x 100 customers = 100 customer hours
1 hour x 50 customers = 50 customer hours
Total outage time = 150 customer hours

CUSTOMER OUTAGE HOURS



As shown, this is an improvement of 40%, which would be reflected in the SAIDI and CAIDI calculations since they are directly dependent on customer outage hours.

Lifecycle management

The high costs of a new substation transformer and long order lead time, averaging around 30 weeks, make the equipment worthy of dedicated planning considerations. Because substation transformers are somewhat unique, including LTCs, MVA ratings, bushing height and location, voltage ratings, alarm capabilities, etc., a perfectly matched spare is rarely available in the neighboring utility's yard or from the re-manufacturers.

The failure mode of substation transformers may seem unpredictable. Because there are no moving parts in the main tank, there is little to be done to maintain the transformer. Most preventative maintenance programs rely on Dissolved Gas Analysis (DGA), Transformer Turns Ratio (TTR) tests, and Power Factor (PF) testing to determine the health of the unit. The TTR and PF tests require the transformer to be taken out of service, but many substation transformers can't be taken out of service easily.

As a result, maintenance programs are often restricted to performing DGA tests on an annual or semi-annual basis with an oil sample being sent into a lab to see what types of hydrocarbon gasses are dissolved in the oil. Based on the type and quantity of the gases, educated guesses can be made about internal arcing and insulation degrading inside the main tank, but in general, nothing can be done about it without shipping the transformer to a repair shop and rewinding it. This is a process that takes a few months, incurs significant financial costs, and results in either customer outages or overloading of other substation transformers.

The reason that transformer failure seems unpredictable isn't because the testing technology isn't proven or the method of determining the health of the transformer isn't sound; it is with the frequency of testing. If the transformer sees a low impedance fault, continuous overloading, or significant overvoltage from lightning, the windings and insulation get damaged at that time. While it may take a few weeks for the damage to cause transformer failure, the timing will probably not coincide with the utility's testing schedule.

Software that continuously monitors assets

Fortunately, there are now continuous DGA monitors available that can be attached onto the main tank drain valve, allowing the monitors to be installed as after-market equipment by the utility's crews. These monitors can detect the dissolved gases within a few minutes or hours and start reporting the change in the transformer's health. Having it report back requires software with communications, and it can report and alarm though the SCADA system.

Note that unpredictable failure of a substation transformer can occur without gassing or ever setting off an alarm, but putting best practices in place maximizes the odds of ensuring the highest level of equipment availability.

Perhaps the greatest value of transformer monitoring isn't in knowing when a transformer will fail, but in knowing that it is still functioning well. Substation transformers are generally depreciated over 30 years. Should a utility invest in several new ones when the old ones are still functional? Without continuous DGA data, it is a difficult decision; it is also a significant investment to buy new transformers and pay for the disposal of old ones while keeping rates down.

Load and resource management

Load management (also known as demand side management or demand response) has been around for more than 30 years. Original systems were power line carriers or radio and relied on one-way communications with a hardwired switch on the customer's equipment. These systems worked but were somewhat "all or nothing;" they had the ability to select a few options such as turning off pool pumps instead of hot water heaters, but generally turned off everyone's pool pump.

Turning off more loads than are needed to keep loads under equipment ratings or to keep from turning the next generator on causes loss of revenue for the utility. Ideally, the utility wants to be right at its equipment ratings and under its contracted wholesale purchases. If the load management solution turns off too much, it results in lower sales. It may also result in a sharp increase in loads (rebound effect) when the timers on the switch at the customers' equipment end the load control period simultaneously.

Additionally, there are constraints on the frequency and duration of load control periods that can create problems. If the operator goes into load control too early, the utility may need to end the load control period prior to the end of the peak because of contractual obligations with the customer. Missing the peak in this way can make the load management system less profitable and extend the cost of recovering the investment in the load management system.

Software with predictive analytics

After years of using these systems, utilities have realized that two-way communications with controlled load are more effective, but many older systems don't allow for that. However, utilities can implement load management software that can forecast the system load and how the controllable system loads will respond to load management signals—without completely replacing older load control systems. The response needs to include the rebound effect caused by appliances kicking into high gear when the power returns.

The software can provide an ongoing way to improve the results of a utility's load management program using trending, modeling, and reporting. The data for such analysis will not come strictly from the load management system but from systems such as SCADA, metering, and wholesale scheduling, which obtained the data. Integration of systems thus becomes a significant enabler of optimizing the use of a program that involves wholesale costs, loads, metering, and demand response controls.

When a utility standardizes its procedures for predicting system peaks and the response that the operators will use, it is much less likely that peaks will be missed outright or that load control will be used too early. It is such tools that enable operators to make informed decisions that are critical to supporting smarter and more consistent grid operations.

Knowledge management

Considering that 40% of U.S. electric linemen will be eligible for retirement by 2013 and 45% of engineers could leave electric utilities by 2015, there is a critical need for utilities to combat the potential "brain drain" that could occur. Knowledge management may be one of the lesser-known functionalities of the smart grid, yet one that can add real value for utilities by digitizing standardized operating procedures for faster troubleshooting and more consistent, reliable operations.

For example, if a lineman with 40 years of experience is always called out when there is a problem on a certain piece of equipment or part of a feeder, he likely has unique knowledge such as how to work a switch or the only line regulator, or the specific understanding that there is smaller wire down the road and that one can't close the loop and tie to another feeder.

Another example is the use of load management when loads are exceeding wholesale contract limits. If the same engineer has always made decisions about when to use load management functions and can generally guess when the system peak will occur, this information would be valuable to others and should be coded and made part of the utility's processes.

Software that digitizes standard operating procedures

To standardize best practices and improve reliability, system operators and linemen must respond in a consistent and timely manner. Knowledge management software captures and electronically manages the knowledge of a utility's most experienced workers and integrates automated and manual processes to deliver interactive, logic-based, step-by-step instructions to guide operators with actions such as switching procedures, outage troubleshooting, or equipment maintenance.

Utilities can leverage knowledge management software to create information-rich, circumstance-based workflows that operators can use to better understand what is happening and to react in a procedural manner every time. It interactively takes inputs from other automated systems such as SCADA, metering, or wholesale cost systems—enabling consistent, reliable work processes, improved quality, and reduced errors, costs, and training.

Extending the smart grid solution

Once the foundation for enabling a smarter grid has been established with the four key functionalities discussed, utilities may then consider some of the following optional capabilities to extend their solution, depending on their needs.

Distribution automation

For increased power reliability, utilities can implement distribution automation (DA), which delivers real-time monitoring and intelligent control outside the substation fence into a utility's distribution lines and equipment. As an extension to a substation SCADA system, it can help utilities gain additional insight into its facilities to minimize unsafe or insecure situations and reduce the number and length of outages.

DA avoids the need for manual switching, significantly decreasing outage time, which also improves SAIDI and CAIDI metrics beyond what a substation SCADA system can deliver. If a section of a line has a fault, the automatic devices (reclosers, sectionalizers, or substation breakers) will open, and the utility can then remotely isolate the problem and back-feed the lines to restore all customers except those closest to the fault.

To leverage the power of DA, a utility needs looped distribution lines and spare capacity in its substations; it also requires the addition of more remotely operated equipment such as reclosers or motorized switches. Therefore, DA is economically viable today for utilities in areas of highly concentrated feeders and system redundancy.

Volt/VAR

Voltage and volt-ampere-reactive (VAR) solutions can help utilities gain more control over reactive power problems. Power factor issues are inherent with AC power systems, especially as customers install more variable speed drives, motors, and florescent lighting.

Since customers are often only billed for kilo-Watt-hours (kWh) rather than kVA-hours, consumers are not incentivized to keep their power factors at unity. As a result, utilities are left to manage VARs on the system or pay for additional wholesale supplies to compensate for poor power factor. Utilities can achieve this by switching in capacitor banks, but they need to manage the increased voltages that occur as a result.

A volt/VAR solution can help improve energy efficiency in a utility's distribution system by gathering information from the distribution system and sharing it with capacitor controllers and voltage regulating equipment. Enabling greater coordination, this type of solution can be an effective way to reduce a utility's wholesale purchases.

Metering

As demand peaks continue to rapidly increase, placing increasing pressure on infrastructure investment, utilities are seeking ways to educate and financially incent customers. To help them more intelligently manage demand, smart metering is increasingly being considered as a tool that can help shape electricity demand patterns in the future.

It's important to note that smart metering alone is not the smart grid. It adds value to critical smart grid functionalities by enabling two-way communications with customers to make them more aware of their energy consumption. It may also facilitate demand control during peak periods by potentially allowing utilities to offer different pricing options based on loads.

Utilities that leverage smart metering may connect it to their energy management systems for greater visibility and control, and gain detailed insight into consumption across their customer base, as well as profiles of different customer types. Furthermore, it could allow greater control over non-critical load, which would increase supply reliability and optimize asset utilization.

Purchasing policies

A final topic to consider is purchasing policies, many of which followed by electric utilities today were created decades ago with a primary focus on ensuring low costs for hardware and commodity items. However, as utilities develop their Smart Grid solution and software comes into play, existing purchasing policies may need to be reevaluated.

The integration of hardware and software components requires openness and the flexibility to move away from point solutions that come from multiple vendors—which have cost, complexity, and maintenance implications—to purchasing holistic solutions.

As a result, purchasing policies need to reflect the implications of selecting the right technologies to support a modern infrastructure. Utilities should ensure that their initial purchasing decisions set a solid foundation that enables them to move forward with seamless interoperability, scalability, and cost-efficiency.

Key questions that utilities may ask themselves include:

- Do our policies require looking at multiple vendors for the purchase of each new software functionality?
- Do our policies allow for evaluating the total cost of ownership, which includes software, hardware, and systems integration?

Conclusion

Moving toward a smarter grid requires utilities to combine the right technologies within a holistic, integrated approach. While there are many products available in the market today labeled “smart grid” solutions, the four critical functionalities—operations management, equipment lifecycle management, load and resource management, and knowledge management—must be present to enable a more intelligent, cost-effective grid.

Utilities that deploy advanced software with these functionalities can gain greater insight through real-time information and analytics, which leads to smarter decision making and helps build a solid foundation for grid optimization. Once these core smart grid capabilities have been established, other functionalities can be added to flexibly extend the solution.

The benefits of a holistic approach should not be overlooked, as it serves as the first step that will help utilities truly capitalize on the intended goals of the smart grid: operational reliability and efficiency. It also sets the stage as utilities progress by enabling easier integration of current and future smart grid technologies, smarter business decisions, and lower total cost of ownership for financial sustainability.

About GE
GE (NYSE: GE) is the world’s Digital Industrial Company, transforming industry with software-defined machines and solutions that are connected, responsive and predictive. GE is organized around a global exchange of knowledge, the "GE Store," through which each business shares and accesses the same technology, markets, structure and intellect. Each invention further fuels innovation and application across our industrial sectors. With people, services, technology and scale, GE delivers better outcomes for customers by speaking the language of industry. www.ge.com

Contact information
Americas: 1-855-YOUR1GE (1-855-968-7143)
gedigital@ge.com

www.ge.com/digital