SUCCESSFUL SMART GRID IMPLEMENTATION

2ND EDITION

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Preface

Planning and implementing a smart grid project can be one of the most complex endeavors that a utility undertakes. The new technologies, integrations to legacy systems, business process transformation within the utility, and customer engagement aspects are multifaceted and interrelated in a way that most operational upgrades are not. The success of a smart grid project can be impacted and even derailed by lack of attention or competence in any one of the many areas involved in the project. The business and customer benefits, however, far outweigh the challenges to implementing and integrating these systems for most utilities, and therefore the risks are worth taking on. Indeed, many of the trends involving distributed energy and renewables make smart grid projects an essential element of the future energy architecture. This sophisticated infrastructure also curbs greenhouse gas emissions, reduces consumer energy bills, and enables a host of further operational business benefits as more systems are layered on. The U.S. Department of Energy undertook a study of four utilities involving 1,250 feeders and found that the System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) decreased 22 percent and 18 percent, respectively. These improvements in operations go hand in hand with better customer service.

A utility's definition of the smart grid depends on factors already in place at the utility, such as the historic or current level of automation and technology investment and what perspective of the smart grid the utility wants to emphasize. For example, these could include customer, distribution, transmission, generation, production, or storage aspects. For most utilities, the business and consumer benefits of advanced metering form the logical starting point because not only is it the norm to have a very positive business case, but it also serves as a foundation for more advanced elements of the smart grid. Those advanced elements, collectively called grid modernization in this book, are necessary for grid reliability and resiliency as more distributed energy resources (DER), such as rooftop solar, are added onto the existing grid and political policies incentivize and force changes in generation sources.

While the smart grid is often described as a revolution for utilities, it is more accurate to describe it as an evolution, though the pace of change has certainly increased. Common attributes of utility smart grid implementations include massive amounts of data, new stakeholders involved in energy system automation, and dependence on communications networks to facilitate interconnection of smart devices and systems.

Success in implementing smart grid projects throughout the industry has been mixed, some major failures have spilled out of trade news into mainstream consciousness. The underlying complexity of the implementation itself coupled with a major change in business processes and active consumer engagement result in many challenges. Indeed, a typical smart grid project usually has components that would be considered large projects in their own right. This book endeavors to distill lessons learned and best practices from successful projects into an understandable guide and roadmap for those starting on their smart grid journey or about to embark on new elements of grid modernization. The reader will be taken through the process from the very first planning steps through operational transition and next steps, though each stage is presented in a standalone manner so readers can jump to the most appropriate stage of the life cycle for their needs.

It is important to note that this book contains advice and guidelines, but it is fully expected that the readers will tailor these recommendations and approaches for their own unique considerations. Success in these projects can and has been achieved by utilities that approach the project with a clear-eyed appreciation of the risks and employ appropriate risk mitigation strategies. We all owe a debt to the first utilities that started smart grid initiatives and to those who continue to advance new capabilities for the valuable success factors and lessons learned that have benefited the industry.

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ELEMENTS OF A SMART GRID PROJECT

The term *smart grid* is generally understood to refer to technology and process updates to bring utility electric, water, and gas delivery systems into the modern age by using computer-based remote control and automation. These systems use two-way communication technology and computer processing techniques to enable a more accurate, responsive, reliable, and automated approach to delivering utility commodities to the customer and enable greater system resiliency and flexibility. The "word" *grid* itself has electrical connotations, but we will use the expansive meaning to include water and gas distribution systems.

The term *smart metering* refers to a subset of technologies supporting smart grid and include advanced metering infrastructure (AMI), meter data management system (MDMS), and customer web portal (CWP) that provide advanced billing functionality and usage information to other systems.

The term *grid modernization*, in this book, refers to advanced technologies used primarily by electric utilities such as distribution management, distribution automation and distributed energy resources (DER) control.

Typical benefits of a smart grid project include the following:

- Improved meter reading accuracy: provides meter reading automatically, transmitted over a communication network.
- Faster response to outages: smart grid equipment helps pinpoint areas affected by an outage and facilitates.
- Deterrence of power theft: benefits all customers by reducing the potential for costly power thefts and thereby protecting rates.
- Enhanced data communication: provides better information and therefore reliability to help manage system operations more effectively.
- Near real-time sensing of power or water quality: enables action to keep the electrical or water distribution system running effectively.
- Integration of DER resources: promotes resiliency and effective use of alternate generation resources.

Smart grid projects are technology- and hardware-intensive, because of this, there is much focus on new systems and their integration with existing or legacy systems at a utility. However, two other primary elements require equally intense thought, planning, and execution for the project to be successful. The business

Integration priorities

The primary interface for any large-scale smart metering system is the MDMS, which forms an integral part of many implementations. MDMS helps utilities process and manage meter operations data as well as meter-read data. MDMS provides a single repository for these data, with a variety of analysis capabilities to facilitate the integration with other utility information systems. The interface with CIS for billing purposes is through the MDMS. Synchronization among CIS, MDMS, and the AMI head-end is necessary to ensure that premise information, customer information, and billing data are coordinated seamlessly.

The most valuable aspect of integrating AMI into the utility suite is the real-time or near real-time information that AMI provides through interval data and events/alarms. Having interval data provides insight and capabilities that were difficult to achieve before and allows for operational improvement that can directly impact utility performance indices. Monitoring power quality information is an important integration required by grid modernization systems such as ADMS and DERMS. The AMI-to-OMS interface is a priority because AMI can help significantly to reduce a utility's System Average Interruption Duration Index (SAIDI). Other interfaces allow consumption information to influence system planning and therefore create more efficient distribution networks based on real usage at time intervals of 15 minutes to one hour, and not just monthly reads. Interfaces with GIS allow spatial display of AMI data over a service territory that can make programs such as theft detection more effective.

Scalable and extensible architectures

Utilities should look beyond old point-to-point integrations where possible and embrace techniques that enhance this data sharing between applications. With the addition of the smart grid's near real-time information into the utility IT/OT environment, the time is ripe for more scalable and extensible architectures such as an enterprise service bus (ESB) approach that connects individual applications through publishing messages to a bus and subscribing to receive certain messages from the bus. Studies have shown that ESB approaches reduce the cost of new interfaces by as much as 50 percent and the cost of maintaining those interfaces by up to 80 percent.

First Steps

As with any large endeavor, the first step in addressing these challenges is to produce a plan that acknowledges and mitigates all these risks, uses the techniques mentioned in this chapter, and leverages the industry lessons learned to produce a thorough plan and roadmap. (Creation of this roadmap is described in the next chapter.) Following these guidelines and lessons learned from past

- Customer and consumer acceptance
- Effect on other utility initiatives or business strategy

Key Chapter Takeaways

- A good business case is credible, practical, and accurate.
- A business benefit is an outcome of an action or decision that contributes toward meeting a business objective. A business cost is an outcome of a decision or action that works contrary to meeting a business objective.
- A business case is built around scenarios, in which one scenario represents the better business decision by comparing projected results from two or more action scenarios.
  - Benefits or outcomes that contribute directly to meeting objectives such as increased revenues, increased margins, cost control or staying within budget, cost savings, and avoided costs are called financial or tangible benefits.
  - Benefits or outcomes that contribute indirectly to meeting objectives such as carbon reduction or societal elements are called non-financial or in tangible benefits. Effort should be made to quantify and turn these into financial benefits for the business case.
- The goal of the cost model is to present in clear and uncomplicated terms the total cost of ownership of the smart grid project for each selected scenario.
- One of the most important sections of any business case is documentation of assumptions.
- The smart grid business case is making a future prediction, based on scientific and rational parameters, but it is still a forecast of the future and is thus inherently risky. A sensitivity analysis can add confidence to the results.

After the vendor short list, the evaluation team reexamines their scoring in light of the short-list presentations, and the VCC is updated. A downselect may occur at this point, or if all of the solutions are still competitive and attractive, all the short-list vendors may proceed to the BAFO process discussed earlier.

While the vendors are responding to the BAFO request, the utility can use the time to conduct reference checks and perform site visits if desired. It is recommended that the utility ask the supplied references for other references for the vendor solution. In that way, references can be discovered that the vendor may not have been willing to share. The utility thus gains additional insight and validation of vendor performance.

Once the reference checks are completed and BAFO have been received, the evaluation team updates the VCC a final time and makes a selection. A final report may also be generated summarizing the process, scores, and selection. The last phase of the vendor selection process is then begun, which consists of the contract negotiations.

Contract Negotiations

The final stage in the vendor selection process is developing a contract negotiation strategy. In order to be successful in the smart grid project, the utility should seek to partner with the vendor and not "take them to the cleaners." Review the objectives for contract negotiation and plan for the negotiations to cover the following items shown in figure 5.3.

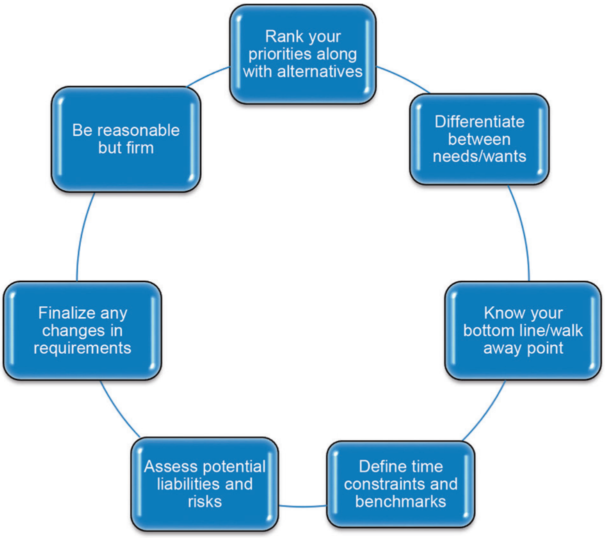

Figure 5.5. Negotiation points

technologies. In this chapter we will examine the technologies associated with phases 1 through 3, and share lessons learned that affect successful project execution. The next chapter will cover the technologies associated with phase 4, grid modernization.

AMI

AMI technologies originally led to the development of smart grid capability and are a foundational element of any smart grid project. AMI is central to a smart grid because without AMI, a utility has neither endpoint usage based on time, nor extensive power quality information. That time-based element is needed to dynamically react to demand and create a more efficient and robust grid that adapts in real time or near real time to events. An AMI project is hardware intensive and involves replacement of meters or modules at every endpoint, which is usually at a customer's premises. Due to this large hardware component, AMI is usually the largest capital expenditure of any smart grid element.

AMI is distinguished from its predecessor, automatic meter reading (AMR), by the fixed communication network and static two-way communications capability of the AMI system. In contrast, AMR systems use a mobile collector, such as a radio-equipped truck, to cruise meter reading routes to collect data. Therefore, while both systems collect metering data, AMR read frequency is similar to manual meter reading (generally once per month) and thus does not have the near real time read capability of AMI that is so crucial for advanced utility applications and business processes.

AMI has three major components: meters or modules, a communication network, and head-end software. These components are shown in figure 7.1. An important concept with AMI is that the system is recording data in intervals in addition to registers. Interval data are simply readings taken at set points in time, usually in resolutions of one hour or 15 minutes for residential applications and more quickly for commercial and industrial (C&I) purposes, with 5 or 15 minutes being common for C&I. Register data are similar to the odometer of a car, recording the ongoing amount of consumption.

AMI meters are the modern, solid-state version of electrical meters that have been installed at homes and businesses for decades. Those older meters were usually electromechanical induction meters, which operated by counting the revolutions of a metal disc that rotated at a speed proportional to the power passing through the meter; thus, the corresponding number of revolutions was proportional to the energy usage. As mechanical devices, these older meters were subject to friction and wear, and suffered a reduction in accuracy over time. AMI meters are electronic and display the energy used on a local liquid crystal display (LCD) and transmit the readings through the communication network to the head-end software.

Demand Response

Demand response (DR), as the name implies, seeks to control or influence the users of the utility's products to reduce system peak usage. At present, the technology is entirely focused on electrical utilities. DR's benefit comes from the fact that utilities by organizational mission or regulatory mandate must provide power at all times, even in the event of rare circumstances like extreme weather. Utility performance is measured by parameters such as the System Average Interruption Duration Index (SAIDI) and the Customer Average Interruption Duration Index (CAIDI). SAIDI is the average outage duration for each customer served, and is calculated by the sum of all customer interruption durations divided by the total number of customers served. CAIDI is the average outage duration that any given customer would experience, which can be interpreted as the average restoration time. According to the Institute of Electrical and Electronic Engineers (IEEE), the median value of both CAIDI and SAIDI for North American utilities is less than 1.5 hours.

Achieving these low SAIDI and CAIDI metrics entails enormous expense in generation and transmission capability, as well as considerable expense in robust distribution systems. Peaking generation plants and the transmission/distribution capability must be built and on standby for those extreme events that tax the system. The effect is most pronounced for Sun Belt states that see their summertime air-conditioning loads increase year after year. DR's primary mission is to address peak events where rare circumstances force a utility to plan for and deliver exceptional power loads. In addition to these peak demand events, a margin of safety must also be held in reserve. Such events may only occur a few times a year. DR can sometimes lower (e.g., by eliminating low-value loads) or shift (e.g., temporarily reduce thermostat settings) the electrical load. Time shifting is illustrated in the simple diagram in figure 7.8.

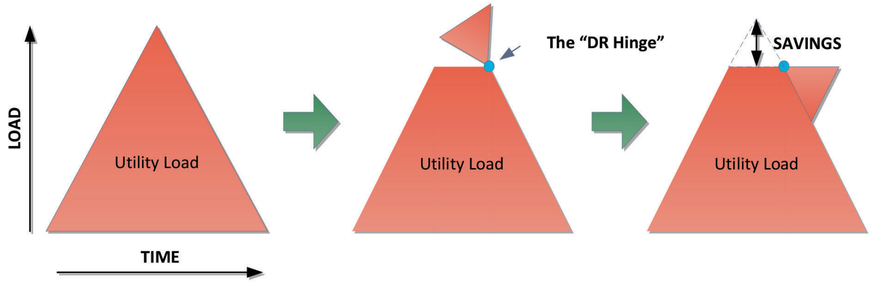

Figure 7.8. The DR time shift

In addition to peak shifting or peak reduction, DR can be used to reduce the aggregate load through vendor or utility control systems to shed loads in response

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ENABLING TECHNOLOGIES – GRID MODERNIZATION

The electric grid is undergoing a major transition and will look dramatically different than the electric grid of yesterday. It will handle complex tasks not originally imagined by utilities, while providing a safe, secure, reliable, and resilient resource to customers. This evolution poses a challenge to the fundamental design of today's grid as emerging features at a large scale, such as renewables (wind, solar, etc.) and other distributed generation (DG) or distributed energy resources (DER), change the fundamental design of steady one-way power flow. In addition, these new sources of power might not be controlled by the utility and could appear as non-dispatchable resources. The way to navigate the complex path forward will differ for each utility; however, new technologies and some common concepts will facilitate the journey for all.

For the past century, the downstream flow of electricity from power generation plants, through long high voltage transmission lines, and then over distribution networks to end users was the norm. The separate domains of generation, transmission, and distribution with defined transition points under the control of a utility led to the safe and reliable delivery of electricity. Historically, distribution systems have been radial configurations, with limited telemetry and with most communications within the domain performed by humans.

Now emerging is the location of DER and third-party renewable sources within the distribution network itself. The result is a dynamic, two-way stream of power, shifting back and forth between some users and the utility. These new generation sources can be owned by third-parties or customers. A utility needs the capability to manage them, and often doesn't initially even have the capability of monitoring affected circuits to identify and avert situations that can upset the safe and reliable delivery of power to customers. The operators at many utilities in the past could only estimate how much power DER and third-party renewables are feeding into the grid. To effectively operate the smart grid, these operators need real-time data, visibility, and control to continue the safe and reliable delivery of power to customers. Five key trends that challenge the capacity of the grid are driving this transformation:

- Changing mix of types and characteristics of electric generation