EXECUTIVE SUMMARY

Southern California Edison (SCE) has a mandate to implement advanced metering technology for its millions of customers. But its first crack at a business case showed existing technology would cost far more than it could save. So SCE went back to the drawing board. Working with EPRI's IntelliGrid program, IBM, EnerNex, and others, they employed a Systems Engineering model and developed a $1.3 billion plan to use technology that didn't yet exist. Through a systematic development of requirements coupled with a careful technical assessment, SCE has crafted a plan whose benefits will break even with its cost. SCE literally designed its own future.

Designing the Future

A SMART GRID NEWSLETTER

CASE STUDY

NOVEMBER 2006

THE PROBLEM

In the wake of an energy crisis, California's Public Utilities Commission ordered utilities to investigate new metering technology and demand-response programs. But when Southern California Edison ran the business case, costs outweighed benefits—by nearly $500 million.

It wasn't long ago that the word *California* was virtually synonymous with *energy crisis*. Increased demand from hot weather, a lack of surplus power, plants undergoing repairs, and inadequate conservation led to rolling brownouts throughout the state. Partial deregulation, high prices, and market manipulation also contributed to a situation that led Governor Gray Davis to declare a state of emergency in early 2001.

Although Davis ended the emergency in November 2003, California's regulatory bodies were concerned about anticipated shortages. Demand-response programs and time-of-use pricing were instituted for large, industrial customers. But new metering and communications infrastructure would be needed to extend those programs to the rest of the energy consumers.

In the summer of 2004, the California Public Utilities Commission (CPUC) ordered its investor-owned utilities to develop business cases for both full and partial deployment of advanced metering (often called "smart meters"). Smart meters can communicate with the utility office, reducing costs, such as manual meter reading.

In response, Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E), and Southern California Edison (SCE) began investigating deployment scenarios. Although some utilities (such as PG&E) gave the green light to existing metering products, SCE came to a different conclusion. Their cost-benefit analysis concluded that existing technology would not be cost effective. Indeed, they concluded that implementing a demand-response system would result in a net loss of nearly $500 million.

During the California energy crisis of 2000-2001, Governor Gray Davis was forced to declared a state of emergency.

THE SOLUTION

SCE crafted a three-phase plan to specify advanced meters with networking and load-control devices while also reducing costs to acceptable levels. Phase 1 (planning, identifying requirements, working with vendors) is approaching a successful completion.

Rather than throw in the towel or burden customers with dramatic rate increases, SCE took a new, visionary approach. "When we looked at existing technology [in the original business case], our approach was largely based on automated meter reading," explains Paul De Martini, director of SCE's Advanced Metering Infrastructure program (AMI).

To make the new system cost-effective, SCE needed to use technology for more than just meter reading. For example, meters with two-way communications allow utilities to disconnect customers for non-payment or reconnect them later without an employee field visit. They can also provide customers with feedback about power rates that change with the time of day (time of use or TOU charges), encouraging customers to reduce consumption at peak hours. And if "load control" technology is also in place, utilities can remotely adjust thermostats for even more savings. (For a discussion these advantages, see the sidebar "From Red to Black: Reassessing the future of advanced metering.")

To gain those benefits, SCE would need a system with (1) the latest meter designs, (2) a communication and network system, and (3) networked devices in customer homes.

"We proposed a multi-phased approach to look at next-generation technology that could create a positive business case," says De Martini. Phase 1, originally expected to last 18 months, called for developing requirements, assessing technology, and performing cost-benefit analyses. Phase 2, also slated to last 18 months, will focus on final development and testing of advanced meters and related products. Phase 3 consists of deploying the meters to millions of SCE customers, a process expected to last four years. The overall program is anticipated to cost $1.3 billion. In 2005, SCE received approval to begin Phase 1. That all-important planning and analysis phase is now approaching a successful completion.

Keys to Success

Although De Martini attributes this good news to some things outside SCE's control (including the Energy Policy Act of 2005 and the support of policymakers, vendor communities, and other utilities), it's clear that several key practices contributed to SCE's accomplishment.

Systems Engineering. Underlying much of SCE's process was

From Red to Black: Reassessing the future of advanced metering

How did Southern California Edison go from a 2005 case study that predicted a net loss of nearly $500M (based on a net present value of cash flow analysis) to a 2006 feasibility report that predicts a $514M improvement? Here are some key differences in the utility's analysis that are expected to make the difference. The dollar amounts represent improvements over the 2005 study (but expressed in 2008 dollars).

Improved communication system coverage. At the time of the original biz case, products were estimated to provide 90% coverage, which means a communications could not be established with a significant portion of customer meters, which would continue to require manual meter reading. SCE now believes 100% can be achieved, reducing meter reading costs and adding more customers to demand-response programs. Some of these improvements arise from the assumed use of an open, non-proprietary communications system, which makes it easier for manufacturers to produce products for the home market that provide in-home displays and encourage customers to take advantage of TOU and critical peak pricing (CPP) rate info to reduce demand. ($45M)

Remote connect and disconnect abilities. Thanks to advancements in technology, utilities with smart meters will be able to disconnect and reconnect customers remotely for non-payment, saving labor costs. Although this feature is expected to increase call center costs (for customer verification before connection or re-connection), the analysis still shows a net improvement. ($298M)

Reduced meter failure rates. SCE's original business case assumed deployment of advanced meters in just under 9 months, posing significant challenges for quality and integration. The new scenario has a more reasonable ramp-up schedule. In addition, improvements in technology has cut the expected failure rate (25% over the life of the AMI system) in half. By incorporating more exacting quality assurance program, SCE expects to reduce meter failure by 50%. Which of course reduces costs for meter replacement, field tests, and reduced exception billing costs. ($33M)

Changes in demand response assumptions. By incorporating in-home display and other devices, the newly envisioned AMI system can incorporate load-control techniques into the system, turning down thermostats and peak hours, reducing the power drain of the many air conditioners in SCE's service area. In addition, TOU pricing and Programmable Communicating Thermostats (PCTs) are expected to encourage a reduction in customer demand. ($315M)

Previously unidentified benefits. In addition to the factors cited above, the new study found benefits arising from transformer overload prevention, reduced "no power" field visits, billing exception processing reduction, summary billing lag, meter reader and field service workers compensation reduction. ($70M)

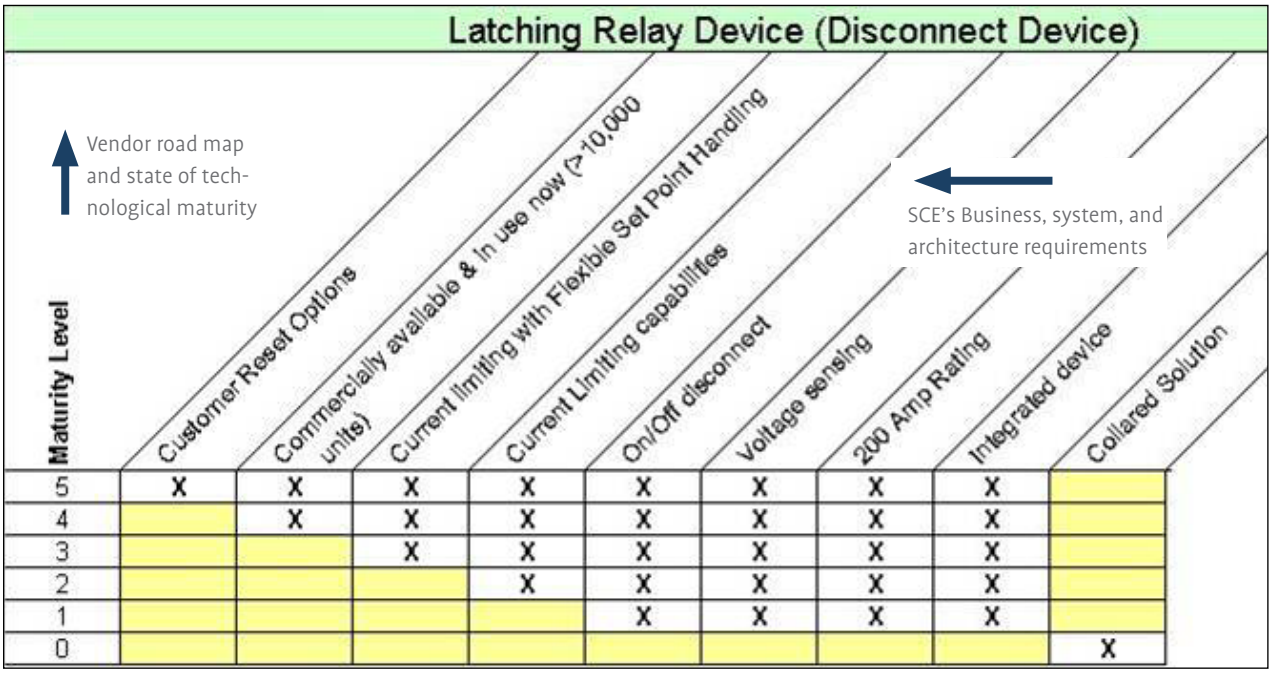
Total cost improvement. Subtracting the $247M cost expected for meters and communications infrastructure, SCE arrives at an estimated $514M improvement in costs over the 2005 business case. ■

an approach known as Systems Engineering, an iterative methodology in which multiple teams drill down from high-level abstractions (e.g., determining requirements) to more real-world specifics (technology and vendor selection). (See the sidebar, "Engineering a System.")

Finding the truth out there. The AMI team began by looking at the state of advanced metering around the world. In addition to noting what other countries were doing, SCE examined the newer grid design principles being advocated by the Electric Power Research Institute's (EPRI) IntelliGrid program. According to IntelliGrid evangelist Erich Gunther, CTO of EnerNex Corporation, SCE actively sought consulting partners who could apply IntelliGrid principles. EnerNex was chosen, along with IBM and KEMA, as consulting system engineers to help define the requirements and identify needed technologies.

Making use of use cases. The first stage in the Systems Engineering approach is to identify requirements for the envisioned system. To do that, IntelliGrid consultants helped SCE develop "use cases," scenarios that identify the people and products that interact to achieve a goal. (For more information, see "The Case for Use Cases.") According to IntelliGrid Program Manager Don Von Dollen, the SCE project represents one of the largest applications of use cases by a utility company. "We conducted over 44 workshops and developed 99 scenarios involving over 140 subject-matter experts. In the end, we fleshed out 18 use cases," he says. As a result, SCE developed over 400 requirements.

Evaluating technology. Identifying needed systems and components is an important part of the Systems Engineering approach. Although SCE was pursuing technology known to be feasible, no available



A Technology Capability Maturity matrix shows the tradeoffs of a given technology at a glance.

products met all the needs they identified. To determine whether a given technology would achieve their goals, SCE incorporated an evaluation process called Technology Capability Maturity (TCM). Each TCM summary consists of a matrix that lists business, system, and architecture requirements along the horizontal access and assigns a maturity level from 0 to 5 on the vertical axis. A TCM matrix for a given device might have a lot of boxes checked off for requirements but score a low maturity level, or vice-versa. A TCM matrix shows the tradeoffs of a particular technology at a glance.

Engineering a System

Leaders of the AMI project at SCE knew that providing new meters and other technology to five million customers was a titanic undertaking. Mounting that effort would require a methodical approach. That line of attack was the Systems Engineering (SE) approach. With systems engineering, a project is broken down into components or layers—a system of systems. The engineers start at the highest level of abstraction at the top layer and work iteratively down to the most detailed level at the bottom. These layers can be grouped according to the kinds of questions they answer—why, what, how, and with what:

Requirements Definition (why invest in this project?) Identifying the requirements is the first step in the process, answering the why question. To do this, SCE developed a series of use cases to determine functional and non-functional requirements and identify the business case for each. Business case teams then assigned a dollar value to each business case.

Conceptual Architecture (What systems, subsystems, and components are needed? Like the requirements phase, use cases provided system architects with fodder for analyzing the messages that pass between identified actors. This became the basis for the list of needed logical interfaces and components.

Logical architecture (How much value does each component yield? The next step is determining what services to provide to meet the goals.

Trade-off Analysis (How much will it cost?) At this level, teams perform a cost-benefit analysis of the systems and components as well as identifying the constraints and boundaries of each.

Reference Architecture (With what standards, technologies, and vendors will we accomplish our goal?) This is the last and most specific level prior to implementation design and deployment. It involves determining the technologies and vendors that will meet the requirements determined in the higher levels. ■

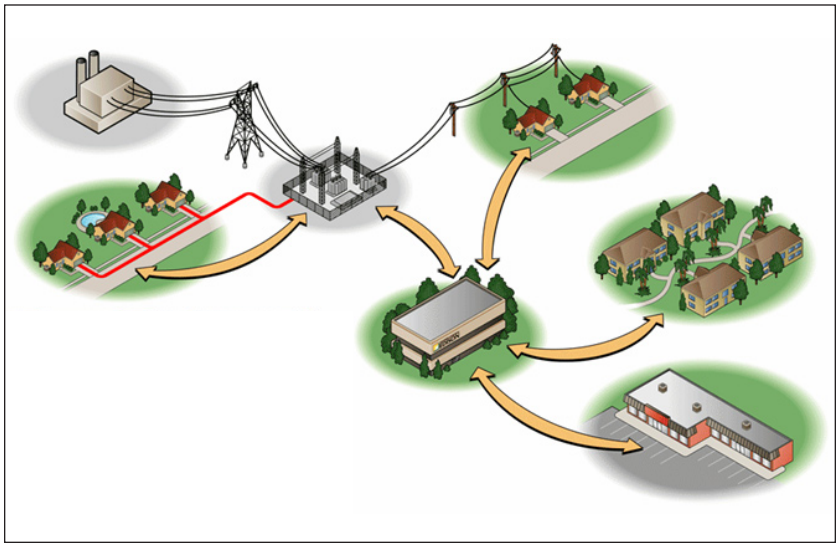
Crafting requirements. Like other parts of the project, developing requirements is not a single step, but an iterative process. It began with high-level concepts in 2005 that eventually were distilled into a more complete set by the second quarter of 2006. The needs identified by the use cases and the information that emerged from the TCM models helped solidify the requirements.

Working with vendors. From the beginning of the process, SCE contacted product vendors that could address the metering and communications needs of the envisioned system. "One of first things we did," says De Martini, "was ask for everybody's product development plans and product road maps." That information provided a baseline. The AMI team monitored the development of those products and provided feedback on SCE's requirements and conceptual needs. "That created a kind of co-development effort with multiple vendors," he explains.

As part of this effort, SCE joined and actively supported UtilityAMI, a forum for defining AMI system components from the perspective of utilities. "Before that group started there were no products that could meet the metering requirements," recalls Von Dollen. "Once the vendors realized that SCE and the other UtilityAMI members were serious about their requirements, they began to react. Now there are at least two meter vendors who meet a large percentage of the common requirements defined by UtilityAMI and the specific requirements published by SCE." (See also "Technology Selection: A time for everything.")

Keeping it open. SCE also followed the IntelliGrid principle of open standards. "We recognized that we did not want a customized product," says De Martini. Requiring open standards helps ensure interoperability with other products, simplifies long-term maintenance, and creates a flexible framework for future products.

Making it available. Related to the use of open standards, SCE's AMI teams have chosen to make most of their documents—from uses



Southern California Edison's Advanced Metering Infrastructure project envisions intelligent meters connected by a sophisticated communications system controlling devices in the home and providing other cost-saving features.

cases to requirements documents to technology evaluations—freely available to the public throughout the process (another practice promoted by IntelliGrid). "Very little of what we're doing is private," says De Martini. "We thought it was important to share information so that others could build on it and give us feedback. And so we would ultimately get a better product from the marketplace." De Martini says such openness was initially met with skepticism but is now well accepted. "We're seeing how being more open and sharing does pay dividends."

Analyzing costs and benefits. As the requirements matured and the technology evaluations developed, SCE personnel were in a position to answer the "How much?" question recommended by the Systems Engineering approach. They updated their cost-benefit projections to make sure they were on track for a cost-effective system. SCE's AMI team published an interim cost-benefit analysis at the end of July in the form of a Conceptual Feasibility Report. They expect to publish a full-deployment business case next summer.

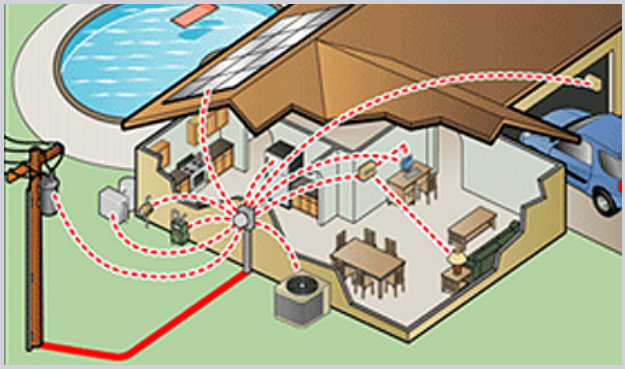
Technology Selection: A time for everything

Not all technology decisions have to wait for the final use case, requirement, business case, and research publication. Instead, the iterative approach recommended by Systems Engineering suggests that teams can take action on a given item when the process dictates, even if other systems are still undergoing evaluation.

A case in point is SCE's choice of the ZigBee communications protocol. SCE's AMI project calls for in-home devices to automatically adjust thermostats and provide customers with rate and power information to help them control usage and costs. To do that, in-home devices need to be able to communicate with each other and with the new power meter, ideally through a simple wireless network.

A core IntelliGrid design principle that SCE followed was the use of standards-based technologies. This quickly reduced the list of eligible technologies to just three candidates – WiFi, Bluetooth, and ZigBee.

These technologies were, in turn, evaluated against non-functional requirements. The ZigBee protocol most closely aligned with SCE requirements and enjoyed support from equipment vendors and the California Energy Commission's Public Interest Energy Research (CEC PIER).



"The requirements process resulted in enough information to analyze the home network technologies early in the process," says Erich Gunther. This relieved SCE from considering multiple options throughout the trade-off analysis, saving time and money. "The early decision also was helpful to vendors to start preparing to respond to an eventual RFP from SCE." ■

BENEFITS

By designing its own future—by researching options, defining requirements through use cases, and working with vendors—SCE has uncovered benefits and cost savings not included in the original business plan. They are starting acceptance testing as they prepare to move into phase 2.

By devoting a significant portion of their process to planning, following principles of modern grid design, and involving others in the process, SCE appears on track to develop a system with significantly greater functionality and cost effectiveness.

"The success of the SCE AMI project so far has a great deal to do the application of a disciplined, systems engineering approach to developing AMI," says Jeff Gooding, senior systems engineer at SCE and lead architect for the AMI program. "It has resulted in an architecture that is extensible and capable of being implemented using available technologies. This approach has produced requirements that reflect the need of a wide base of stakeholders from both inside and outside SCE. The methodology allowed continuous involvement of the vendor community to ensure that they understood the requirements and provided valuable feedback to SCE to validate that the implementation was feasible."

Indeed, one reason for the 18-month schedule for phase 1 was that vendors needed that much time to develop the requested

Snapshot: Southern California Edison

Along with Pacific Gas and Electric (PG&E) and San Diego Gas and Electric (SDG&E), Southern California Edison is an investor-owned utility (IOU) governed by the California Public Utilities Commission. Unlike its sister IOUs, however, SCE provides only electricity, not gas.

A subsidiary of Edison International, SCE grew out of companies that began generating and distributing power to California in the nineteenth century. Today, SCE provides daily electricity to 13 million people in 430 cities over an area of 50,000 square miles. They also supply power to commercial and industrial customers, including 5,000 large businesses and 280,000 small ones.

SCE employes approximately 15,000 people and has consolidated assets estimated at $25.3 billion. ■

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"If we had not used the IntelliGrid model, it would have added six to nine months to our process."

—Paul De Martini, SCE AMI program director

technologies. According to De Martini, these new devices "didn't even exist last year when we got started." As of September, however, SCE received the first next-generation metering system for evaluation. It's currently undergoing acceptance testing to ensure that it meets safety and environmental standards. They are expecting to receive several other meter products in the next few months.

Employing use cases also paid off. "The IntelliGrid use cases really helped jump-start our process," De Martini reports. "If we had not used the IntelliGrid model, it would have added six to nine months to our process."

SCE's willingness to share information also benefits other utilities. "They're giving the industry back the results of everything they've been doing," says IntelliGrid Program Manager Don Von Dollen. "That provides a starting point for the next utility that wants to do a project like this. They won't adopt exactly what SCE does, but it lets them pick and choose what they want and puts them that much further ahead of the work."

Collaborating with vendors, utilities, and other organizations pays off in multiple ways. "SCE recognizes that they will get better response, better pricing, and better vendors if those vendors know SCE is not the only utility that wants these products," explains EPRI's Don Von Dollen.

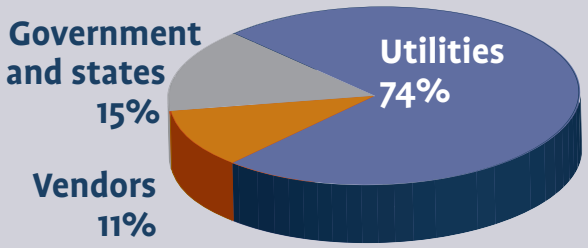
Snapshot: IntelliGrid

The IntelliGrid program was created by the Electric Power Research Institute (EPRI), an independent non-profit association for energy and environmental research. IntelliGrid envisions a grid that links relays and sophisticated protection schemes together with the latest communications technology as well as distributed computing and intelligence technologies, resulting in more globally optimized, self-healing systems that are flexible, extensible, interactive, and secure.

A major achievement of the program is the IntelliGrid Architecture, an open, standards-based architecture for integrating data communications networks and equipment needed to start creating the smart grid today. The IntelliGrid Architecture provides the methods, tools, best practices and recommendations for specifying "intelligent" systems so that today's investments are not wasted on systems or equipment that will need to abandoned or re-engineered later.

EPRI is documenting and disseminating such demonstration results so that specifications and design processes can be applied by any utility, and adapted as needed. ■

For more information, see
www.epri-intelligrid.com
www.IntelliGrid.info



IntelliGrid funding sources

LESSONS LEARNED

SCE still needs to define security issues and faces the daunting task of implementing never-before-tried technology in the homes of millions of customers. But the methodical processes they have adopted have made for an unqualified success so far.

Although SCE has only completed the first of three phases of this far-reaching multi-year project, the utility is in the enviable position of having made no significant missteps. In fact, phase 1 of the SCE AMI program will come in five months ahead of schedule and under budget as well. "I'm not sure there is much we would have done differently," says De Martini. "There hasn't been anything that we didn't expect—except that vendors have responded more quickly. Other than that, it's pretty much gone according to plan."

Nevertheless, the AMI project still has a long way to go. Security aspects are still under discussion. And products have yet to be tested and integrated. "Getting new meters working on a scale of five million customers has never been done," notes De Martini. "Working on this scale is breaking new ground." ■

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