EXECUTIVE SUMMARY

When it comes to modernizing the nation's vast electrical grid, the discussion often centers around hardware and technology: How much can "smart meters" save us? What problems can a common communications platform prevent? How do we integrate wind and solar options?

But one of the most basic challenges has little to do with technology and a lot to do with the process used to upgrade. A case in point is Phoenix's SRP power district, which recently integrated a substation's collection of intelligent electronic devices (IEDs). Results there suggest that successful grid modernization depends in part on modernizing the processes used to identify project requirements. And, thanks to concepts promoted by the Electric Power Research Institute (EPRI) IntelliGrid℠ program, companies like SRP are learning a new way to establish requirements by implementing a strategy developed for other industries: use cases. This new approach initially takes more time and money but in the long run may reduce costs as much as 20%.

The Case for Use Cases

A SMART GRID NEWSLETTER

CASE STUDY

SEPTEMBER 2006

THE PROBLEM

Phoenix's SRP power district needed to integrate system sensors at the Browning substation to optimize performance and maintenance, forecast problems, and avoid catastrophic equipment failures. But how could they be assured they would end up with a system that fulfills all these needs?

A substation transformer going up in smoke can cost millions of dollars to replace.

For residents of Phoenix, the summer of 2004 was hotter than most—and the weather had little to do with it. In June of that year, a failed relay and employee miscommunication about a breaker led to power flowing into a transformer at West Maricopa County's Westwing substation, operated by Arizona Public Service Company, and jointly owned by Arizona's power district, SRP (see the sidebar "What is SRP?"). Pressure built up in the transformer, resulting in a July 4 conflagration that ultimately destroyed five transformers. Without the transformers, the area was limited in its ability to import power. Residents were asked to turn up their thermostats to stifling levels. Many retailers even kept lights off during business hours.

Catastrophic failures such as the Westwing fire can cost tens of millions of dollars. The value of managing risk on such high-dollar assets, especially those critical to keeping the lights on, became too apparent.

To prevent such calamities, SRP tackled the challenge of integrating dozens of sensors and intelligent electronic devices (IEDs) at its Browning 500/230kV station in early 2006. They already have over 50 such devices but no consistent means of getting information from them. "The challenge was that most of them had their own proprietary software to bring the data back," explains John Blevins, SRP's manager of Power Quality Services. Some devices allowed remote communication, while others required site visits to download data.

The 2004 fire at the Westwing substation took out five transformers.

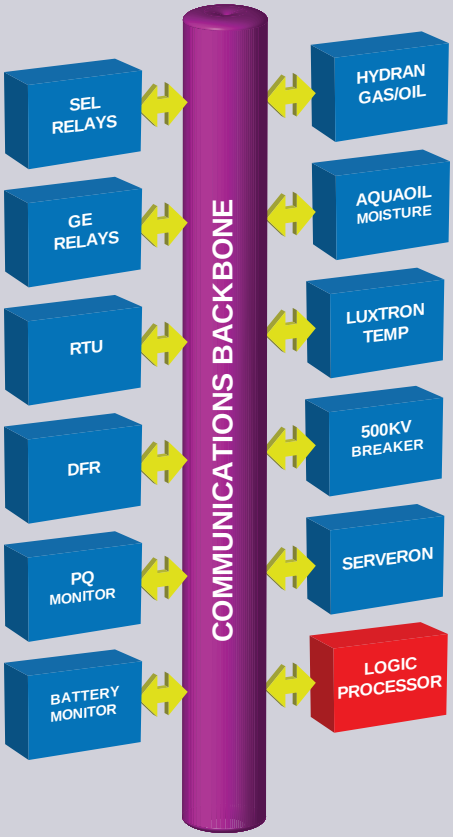
To be truly useful, they needed an integrated system with intelligence and notification features that would provide useful non-operational data and analysis tools right to the desktops of SRP's engineering and maintenance staff. Such a system could warn of problems before a disaster occurred. (See the sidebar, "Integrating Browning's many devices.")

Integrating Browning's many devices

SRP's Browning 500/230kV substation already had numerous intelligent devices and sensors producing a lot of raw data. What it lacked was inter-device communication and alarm notification. The system needed to be integrated in a way that could convert massive data into information that was available securely throughout the company. "The main purpose of the project was to have a single system that constantly watches transformers (temperatures and moisture or gases), relays, digital fault recorders, breakers, and station batteries to ensure everything is working as it should," explains SRP's John Blevins.

To do that, SRP added new hardware (including an additional server connected to the enterprise server) and software to create a data backbone using a common information model that lets each of the applications communicate with the new system. The data is integrated into a common database for logic processing.

A key software product that the team settled on is a product called My IEDs™ from Subnet Solutions. This IED connection management tool shows users a list of substations and devices they have permission to access and provides those users with information on the desired device. "Employees in the field and in SRP offices can log in to the SRP intranet and get the information they need," says Blevins.



The software also includes intelligent notification features. For example, If a critical threshold has been reached for a particular device, My IEDs knows the proper person to contact to address that specific problem.

Another decision in the integration process was which communications protocol to use. "The IntelliGrid Architecture normally steers people toward IEC 61850" (an international standard), reports Blevins. "But our people weren't interested in employing that protocol. We are a DNP3 [Distributed Network Protocol] shop, so we decided to remain consistent."

IntelliGrid's Don Von Dollen doesn't see that as a problem. "DNP3 and IEC 61850 are just two out of many candidate technologies in this space," he notes. "IntelliGrid is all about capturing requirements first, and then mapping those requirements to suitable technologies second."

THE SOLUTION

For years software companies and other high-technology firms have employed "use cases" to identify and document project requirements. Use cases consist of scenarios describing how actors interact with a system to accomplish a goal. IntelliGrid is adapting these techniques to the electric power industry.

To help SRP develop a strong set of requirements for the project, Blevins introduced processes advanced by IntelliGrid, an international consortium that seeks to develop the infrastructures necessary to support the next generation of energy delivery (see the sidebar, "What is IntelliGrid?"). Blevins was familiar with IntelliGrid's work, having served as SRP's representative on IntelliGrid's Steering Committee. Indeed, SRP was one of IntelliGrid's original funders. He contacted IntelliGrid Program Manager Don Von Dollen, who provided a workshop for approximately 30 SRP employees from different departments. After that, SRP did most of the work of developing requirements, with EPRI staff and consultants providing review, support, and consulting.

What is SRP?

The term *SRP* applies to two entities, the Salt River Project Agricultural Improvement and Power District (a government agency) and the Salt River Valley Water Users' Association (a private company). The power district is part of Arizona state government and provides electricity to approximately 860,000 customers in the Phoenix area. It runs or cooperates in 11 power plants, as well as numerous smaller generating stations. Energy sources include oil, coal, thermal, nuclear, natural gas, and hydroelectric.

SRP (headquarters)
1521 N. Project Drive
Tempe, AZ 85281-1298
(800) 258-4SRP (4777)
www.srpnet.com

SRP
Delivering more than power.

Making use of use cases

To ensure success, the project needed to identify all the hardware and software requirements (see the sidebar "Why do projects fail?"). To accomplish that, IntelliGrid advocates developing a collection of "use cases." Software and other high-technology companies have employed use cases for years to identify and document project requirements. Indeed, use cases were originally developed for the software industry by Ivar Jacobson. Now IntelliGrid team members are showing how developing use cases can be extremely valuable for the power industry as well.

Use cases consist of scenarios—stories—that describe how actors interact to accomplish a specific goal. It involves identifying the actors (which may be a human being or a piece of hardware), and the goals of those actors. Participants identify the steps the actor takes and the responses of the system to the actor's actions. One or more scenarios may be needed to describe how the goal is achieved. (See the sidebar, "12 Steps to a Use Case.") The use cases are then documented and reviewed to ensure that the needs of all stakeholders have been captured.

What is IntelliGrid?

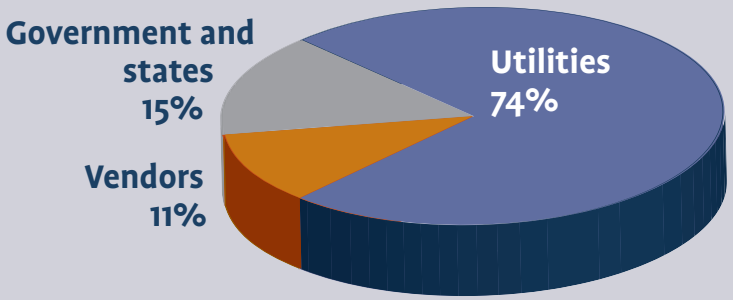
The IntelliGrid consortium was created by the Electric Power Research Institute (EPRI), an independent nonprofit association for energy and environmental research. Currently, power systems devices such as electronic protective relays and sophisticated protection schemes already provide local intelligence. But IntelliGrid envisions a grid that links these systems 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.

The first projects for creating an intelligent grid are underway at several utilities in the U.S. and Europe. Several of these projects, like substation automation at SRP, are employing or adapting IntelliGrid Architecture.

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

Why do projects fail?

Many attempts to modernize or improve an existing system involve developing or purchasing a new technology and grafting it on to an existing system. Because the existing system wasn't designed to work with the new technology, engineers have to develop an integration system to connect the two. Unfortunately, the next time another change is needed, still another "one-off integration" has to be created to accommodate that. Each new addition or upgrade is integrated in an ad-hoc manner without an overall direction that will allow growth without constant re-engineering. "Any competent engineer can find a way to glue any two systems together to make them work," says Erich Gunther, CTO of EnerNex and IntelliGrid evangelist. "That's what they do. What takes a little more work and thought is to glue those systems in a way that is extensible, scalable, manageable, and secure." Without a plan—an architecture—projects face added expense as each new system has to be redeveloped.

Gunther sees the problem as a failure to clearly define requirements of a system in advance. "A requirements-based approach lets you understand the information from the start and create policies to manage it," he says. Unfortunately, too many companies gloss over or skip this step entirely. The result is products that don't perform as desired (both practically and in the marketplace), and projects that require costly reworking. The expense of rework increases exponentially the later errors are discovered. Robert N. Charette, writing in IEEE Spectrum magazine, reported that billions are lost each year on bad software and IT failures. Among the top reasons mentioned for project failure was "badly defined system requirements." "It's kind of like knitting a sweater, " writes Charette. "If you spot a missed stitch right after you make it, you can simply unravel a bit of yarn and move on. But if you don't catch the mistake until the end, you may need to unravel the whole sweater just to redo that one stitch." (Robert N. Charette, "Why Software Fails," http://www.spectrum.ieee.org/sep05/1685.)

Every year dozens of technology-related projects are abandoned as inadequate or arrive late and over budget. The causes are many, but failure to identify requirements with care and accuracy is chief among them.

According to Gunther, the consequences of bad or missing requirements also include squandering resources on unimportant features, incomprehensible user interfaces, incompatible interfaces and products, missing architectural elements, unsafe user environments, untestable features, and the need for rework when errors are discovered.

Conversely, capturing requirements accurately can help set priorities for limited resources, provide ammunition to resist scope creep, supply a common language for team members, simplify the writing user documentation, enable the auditing of a project for traceability, and ensure quality that can be tested.

To be effective, requirements must be captured and communicated. "Requirements are useless if only one person or group knows them," notes Gunther. "Someone must be responsible for implementing, testing, and supporting them."

Done properly, the use cases that a team develops readily translate into a project's functional requirements (i.e., what a system must *do*). For example, a functional requirement might state, "The meter shall time stamp measured values." But projects also need to capture nonfunctional requirements (constraints, behavior, performance targets — what a system must *be*). For example, a nonfunctional requirement might state, "The meter shall produce data time-stamped to 10ms resolution with 1ms accuracy."

"The overall scenario describes the functional requirements," notes Von Dollen. However, use cases are not very good at capturing nonfunctional requirements. Consequently, IntelliGrid recommends following up with additional brainstorming meetings to identify these nonfunctional requirements.

Von Dollen estimates that in a case like SRP's, capturing requirements can take one or two man-weeks at the beginning of the project to create the use cases. This is followed by several more weeks to carry out workshops, brainstorming, and reviews. Finally, the information must be documented. The total amount of time required varies greatly with the size and scope of the project.

How did SRP take to the new methodology? "Some of our people were initially skeptical of the process," admits Blevins. After all, they reasoned, they had done many such projects before without employing use cases. Why start now? But "the IntelliGrid team showed us why," he says. "They were able to come in and walk us through the process and teach us how to develop use cases." Despite previous misgivings, Blevins reports that team members are now sold on the process.

The project was brought to a successful completion this year.

12 Steps to Effective Use Cases

1. Name the system scope and boundaries.
2. Brainstorm and list the primary actors.
3. Brainstorm and exhaustively list the user goals.
4. Capture the outermost summary use case for each primary actor (see who really cares).
5. Reconsider and revise the summary use cases.
6. Select one use case to expand.
7. Capture stakeholders, interests, preconditions, guarantees.
8. Write the main success scenario steps.
9. Brainstorm possible failure and alternate success conditions.
10. Write the alternate scenario (extension) steps.
11. Extract complex flows to sub-cases, merge trivial ones.
12. Readjust the original set of summary cases.

Source: Alistair Cockburn, *Writing Effective Use Cases* (Boston: Addison-Wesley Professional, 2000).

BENEFITS

Developing and documenting use cases helps team members establish clear and comprehensive project requirements. They save money in vendor bidding and reduce long-term maintenance costs. At the same time, use cases capture expert knowledge and help ensure buy-in from stakeholders.

One obvious benefit of developing use cases is that it can help members of a project team really understand the problem and what it will take to solve it. But the benefits go beyond teamwork and understanding to include cost savings, risk mitigation, and more.

Counting costs

Although little hard data is available, use cases appears to promise significant cost reductions.

Pay now, save later. For example, well-developed requirements can reduce the risk of rework later on. And those benefits mean saving money in the long run. "The first time you take this approach, the additional training required means it will be 15% to 20% more expensive," says IntelliGrid consultant Erich Gunther. "But the second, third, and fourth times are maybe 20% less than the old approach."

In the case of SRP, capturing use cases did add some extra time and cost, Blevins admits. "Creating use cases is time consuming," he says. "But the requirements are captured in more thorough detail when you use the IntelliGrid process. And when we apply this to the next receiving station, it will be easier because the requirements are so well documented." SRP has a number of receiving stations that may be candidates for IED integration, and Blevins looks forward to reusing the use cases for those projects. "I think it will drive down the cost dramatically."

Vendor saints go marching in. IntelliGrid promotes the selection of open standards when mapping technologies to systems requirements. Because use cases focus on scenarios, not technology, the resulting requirements lets companies pick the technology that best satisfies the requirements. Focusing on open standards helps keep companies from being dependent on a single vendor or contractor and increases choices. This in turn leads to more cost savings. "If we bid capital equipment, it generally comes in at 20% to 25% lower cost than if we sole source it," says Joe Hughes, project manager for the IntelliGrid Architecture.

The use case scenarios also made it easier for SRP to communicate with bidding vendors. "We got feedback from suppliers that the documentation was very helpful," says Blevins. "The uses cases provided backup documentation that a vendor could consult if they weren't sure what they were asking for."

Built to last. Hughes also points out that having detailed, forward-looking requirements reduces the

By the numbers

Estimated cost of the employing the use-case approach for the very first time:

15-20%

Estimated cost savings over previous approaches thereafter:

20%

Estimated cost savings from getting bids from multiple vendors:

20-25%

Cost of integrating one substations IEDs with new communications backbone:

$250K

Cost saved if a transformer loss is prevented:

$3M

need to constantly upgrade and replace hardware. "For example, desktop computers get replaced every few years. That's not realistic when it comes to deploying something like a metering system. Those need to last for decades." The better your requirements documents, the more likely you are to get products that will last.

My so-called life cycle. In addition, there are costs associated with product life cycles. As one part in an ad-hoc system becomes obsolete, it may be difficult or impossible to come up with a custom patch to fill the gap or interface the remaining pieces. "Maintaining this patchwork quilt can be hugely expensive," observes Hughes. Following carefully crafted requirements that include interoperability and open standards can avoid this problem going forward.

Miscellaneous savings. Blevins notes that the IntelliGrid process has other undocumented savings. For example, the SRP integration will result in a reduction in the number of engineering and maintenance field visits, reduction in unscheduled outages, and opportunities for just-in-time maintenance. Those add up to cost savings.

Mitigating risk

Naturally, the cost of hardware needed to complete a project doesn't change. In the case of SRP's Browning 500/230kV substation upgrade, the equipment alone cost about $250,000 per substation. But if the process SRP follows succeeds, they'll be able to prevent the failure of high-voltage transformer, which can cost up to $3 million. "We cost justified this project based on the risk mitigation alone," says Blevins.

Documenting expertise

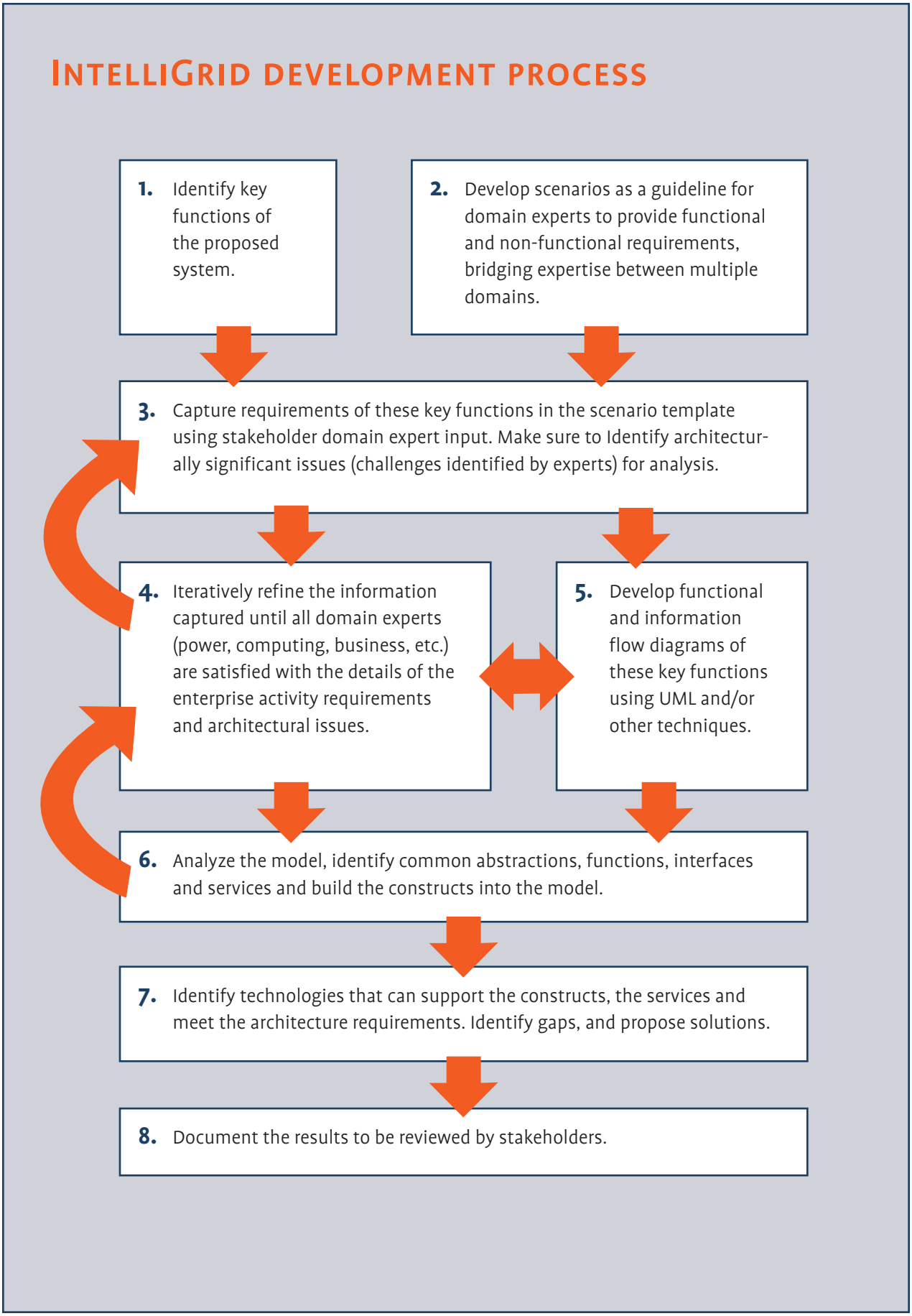
A side benefit of developing use cases is that it helps uncover and document buried institutional knowledge that can disappear as employees retire or move on.

Documented use cases and requirements may even help companies for which they were not originally written. "EPRI will keep a library of uses cases like ours and that of Southern California Edison," notes Blevins. "These will be useful to anyone who wants to use them. Once the repository is established, users won't have to start from scratch. They will be able to download them, change them, and maybe rethink their own requirements." (For more on this repository, see http://www.epri.com/intelliGrid/deliverables.html.)

Teamwork and stakeholder buy-in

Another benefit comes from researching and developing uses cases: Consulting with users and stakeholders on system requirements can help build consensus in an organization for the type of project that is needed. "The use case approach drove a lot of teamwork," says Blevins. "Project managers alone can't develop use cases. Users have to be involved." For the Browning integration project at SRP, users from more than a half dozen departments teamed up to participated in the program. "It makes them take the time to think how they will get the most out of the technology."

IntelliGrid development process



LESSONS LEARNED

In employing the use-case approach in the electric power industry, SRP chose to adapt IntelliGrid techniques and standards to suit their needs. Changes include modifying terminology, choosing a different communications protocol, and adopting table-based documentation for uses cases and requirements.

For the Browning project, SRP and IntelliGrid consultants appealed to the engineers' experience by taking a tabular approach to capturing use cases

As SRP and IntelliGrid savants worked through the use-case process, they learned that what works well in the software and IT industries requires some translation when applied to electricity companies. "What we've done is try to take away some of the baggage that IT folks are familiar with and instead make it useful to an electric power engineer," says Joe Hughes. To do that, they've streamlined and customized the process, and revised the terminology.

More than just words

This customization process goes beyond changing a few words. Software companies employ what is called Unified Modeling Language (UML) to document use cases. UML is an object modeling language with a system of graphical notation to help diagram the story behind a use case in an unambiguous way. Although IntelliGrid has used this technique with some clients, such as Southern California Edison (http://www.sce.com), "it was clear that it just wasn't going to fly with many power engineers," says Hughes.

The Browning project at SRP was just such a case. "They tried to persuade us to use UML," Blevins recalls. "But UML didn't work for us because of the steep learning curve. We felt like we couldn't afford the time required to learn to effectively use UML for this project."

Turning the tables

Consequently, a different tack was taken with SRP. "Engineers like tables," Hughes notes. "Instead of UML diagrams showing interactions, we put the main data in a table called a message matrix." This table shows a list of actors, the functions they perform, and so on.

The tabular approach also worked better in capturing nonfunctional requirements. While talking to stakeholders, participants could ask, "How fast? How often? How reliable? How secure?" and capture that info in table form.

Flexibility

As with recording methods, there is no set number of use cases that works for every project. "SRP came up with approximately 8 use cases," recalls Hughes. "Southern Cal Edison (a very large project), on the other hand, had 18. The average is around 10. But having more than 20 starts getting hard to handle and comprehend."

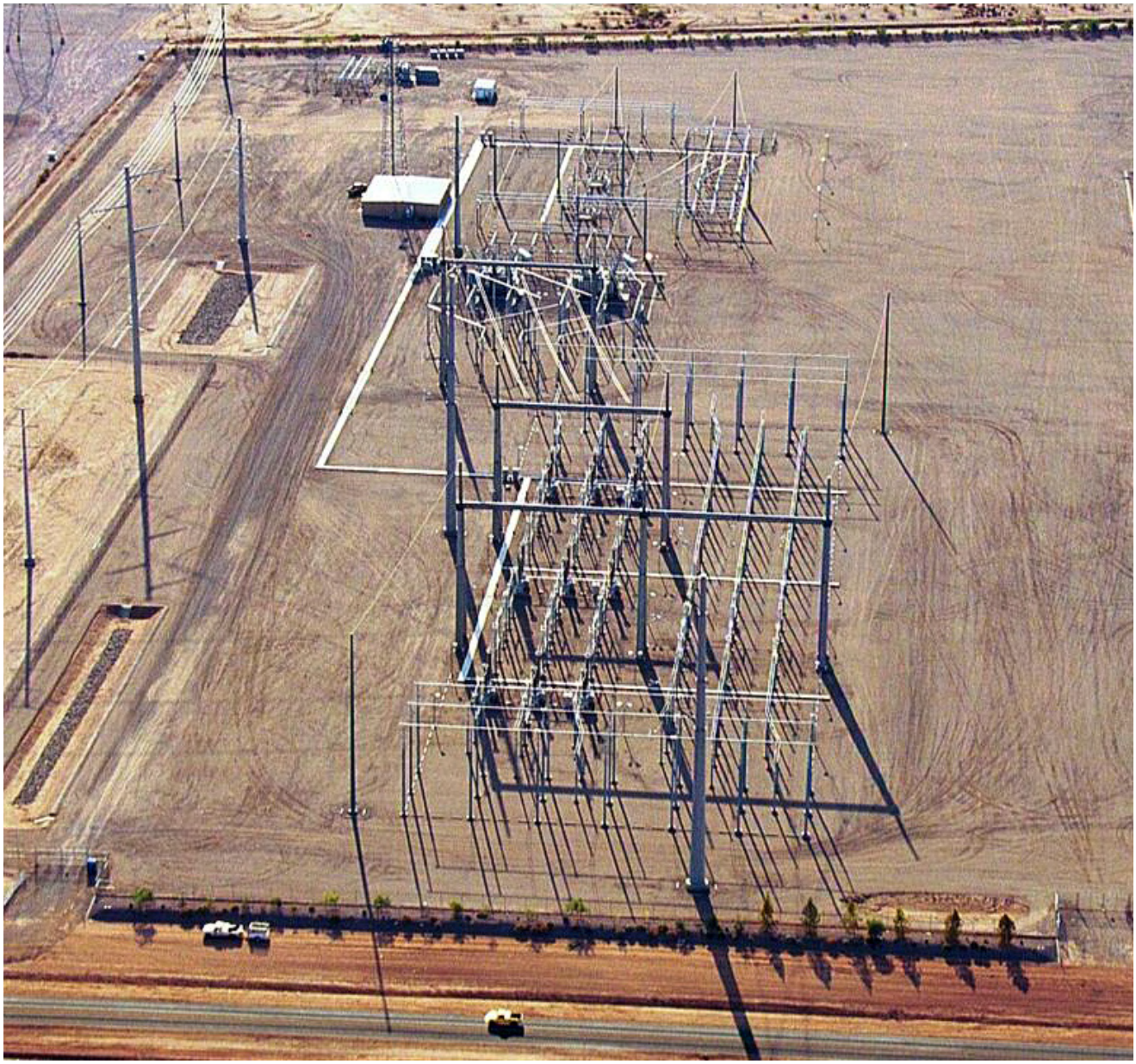
Case studies at Smart Grid News

This article is one of a series of case studies created as part of a cost-shared, public-private initiative with support from the Office of Electricity Delivery and Energy Reliability and U.S. Department of Energy and produced by Smart Grid Newsletter and Global Smart Energy. You'll find a growing library of position papers, case studies, and third-party reports of pilot installations at www.smartgridnews.com. Contact us for a quote on your needs.

Capturing other benefits

For future projects, Blevins would like the use case analysis to go even further in estimating savings. For example, the newly integrated equipment and communications backbone means employees can spend less time driving to substations to make visual inspections. Blevins would like to know how much money is saved by the reduced number of field visits and drive time.

Although the expected monetary benefits of this approach may not be achieved for some time, IntelliGrid has found that use cases are proving to be an effective way to get a group of experts and stakeholders to start thinking about the processes they already have and the functions they need to develop.



Use cases played a valuable role in IED integration project for the Browning 500/230kV substation.