PLM and steam generator replacement at SONGS

BY STEVE STEPHENS

Simulating complex nuclear plant projects in virtual 3-D reduces uncertainty, costs.

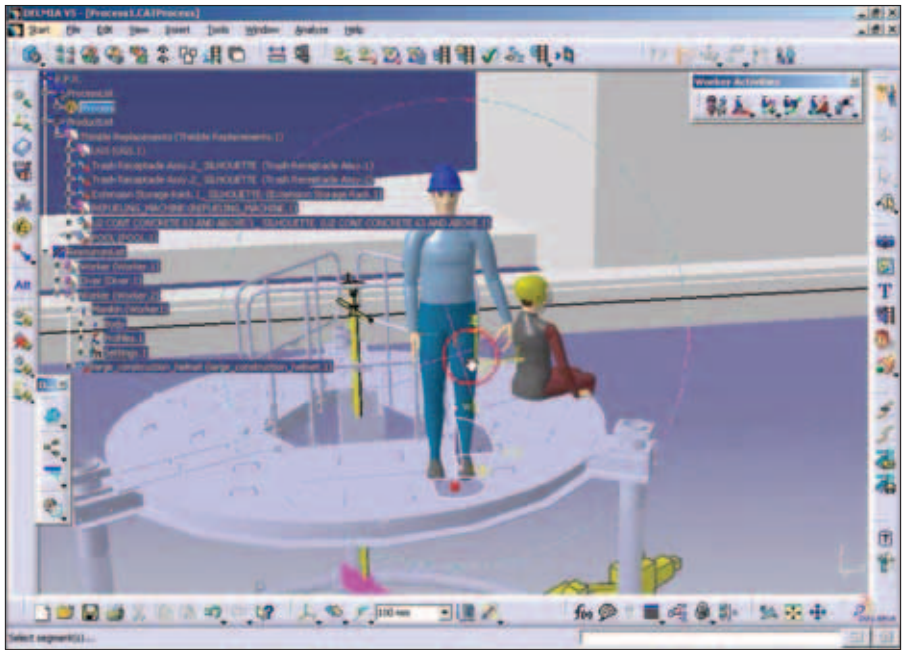
EVEN BY NUCLEAR power plant standards, the steam generators at Southern California Edison's (SCE) San Onofre Nuclear Generating Station (SONGS) are enormous. More than 65 feet long, nearly 23 feet wide, and weighing 621 tons, each of the four steam generators—two each for Unit 2 and Unit 3—measures roughly twice the size of those in use at most nuclear power plants.

Replacing them, as SCE plans to do in 2009–2010, at a cost of $680 million, involves massive challenges, beginning with moving the generators to and from the plant. The new steam generators will be moved on ships and barges, and possibly on trucks, to the plant site.

But even the transportation challenges do not compare to the difficulties of installing the new steam generators. Openings will have to be cut in the containment buildings and the steam generators maneuvered onto their sides for removal and replacement. Crane operations to remove the old units and replace them with the new ones will involve weights that will shift significantly as the steam generators are moved from a vertical to a horizontal position for removal, a procedure that will be reversed for installing the new units. At some stages, clearances measure mere inches.

With no second chances and no trial runs, the team must do the project right the first time: Opportunities to practice or conduct physical mockups simply do not exist. In addition, the shutdowns will cost SONGS $1 million each day just for replacement power (at 4 cents per kilowatt), and so any overlooked steps or unanticipated challenges could send costs soaring.

Still, engineers at SONGS are confident that they can accomplish the work on time and on budget, thanks to the company's adoption of a product lifecycle management (PLM) strategy. The aerospace and automotive industries for years have used PLM, a business strategy that includes the use of a sophisticated suite of 3-D design, modeling, and simulation software and processes. But SONGS engineers are the first to apply this strategy to the nuclear industry, using PLM to plan and validate major operations involved in replacing the steam generators. From analyzing lifting tolerances and clearances to accurately predicting staffing needs, this powerful and highly accurate virtual 3-D capability helps identify and resolve in advance the issues inherent in such a massive undertaking, with more certainty and at significantly lower cost than current physical prototype methods. SCE believes in PLM so much, in fact, that the company has already built a requirement for 3-D simulations into its bid requests.



Human ergonomic and 3-D simulation of the reactor pool and thimble replacement project begins in this image from the digital manufacturing/simulation software used by SONGS.

3-D simulations

SONGS is using a software portfolio from the Paris-based company Dassault Systèmes that has been used in the aerospace, automotive, and shipbuilding industries. The software creates accurate 3-D digital models of new projects and equipment slated for upgrades and then assembles these models into digital mockups—3-D visualizations of complex equipment assemblies that can be studied from all angles. Software also manages the relationships among various disciplines of design data, applying restraints and standards to alert design engineers to clashes or inadequate clearances and ensuring compliance with the company's design standards, as well as Nuclear Regulatory Commission regulations.

Preparing for the steam generator replacement project, however, required more than the ability to create mockups of the facilities. Also needed was the ability to simulate complex operations within the mockups—for example, to simulate the stresses on key pieces of equipment, such as the

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crane that will be used to lift the steam generators. Planning was also needed to determine where to cut the openings in the containment buildings and how to relocate major cables and other equipment displaced by the openings. In addition, project management wanted an accurate estimate of the time required for each step in order to develop safety procedures, staffing estimates, and cost forecasts. Dassault Systèmes' process simulation software provides these capabilities.

Armed with the appropriate software, SONGS set out to test whether PLM could do all that the steam generator replacement project would require. To accomplish this, a test simulation was first conducted on a different but similarly complex project: the replacement of the plant's thimble rods.

Validating PLM

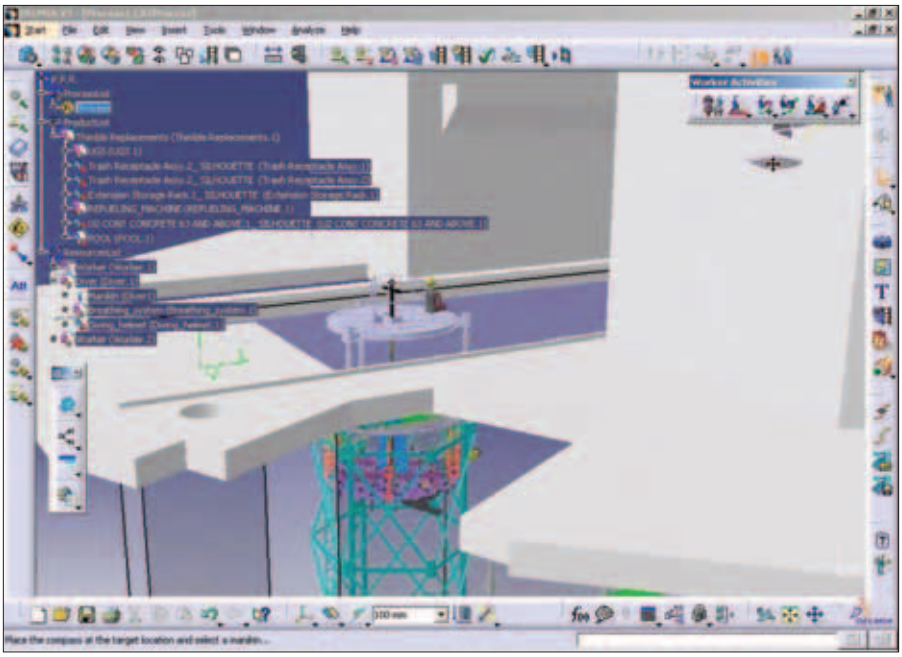
SONGS led the nation in recognizing that normal thermal growth in the plant's thimble rods created assembly challenges that required rod replacement. Since then, 10 other reactors have encountered the condition.

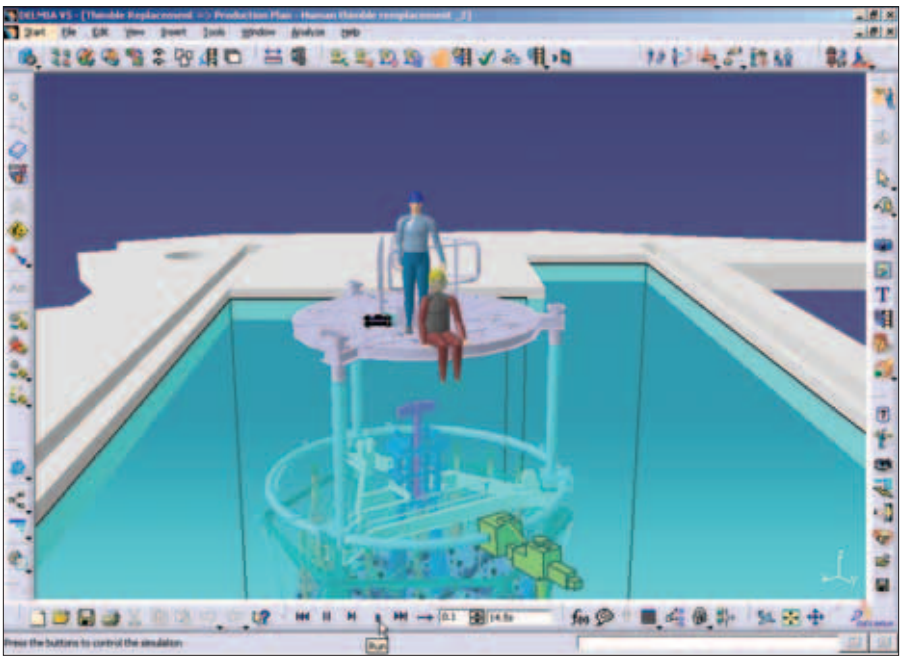
A pool of water surrounds the radioactive rods, so replacing them required the use of divers, who must work in limited shifts to manage their radiation exposure. Ensuring the safety of the divers while keeping the project on time and on budget required flawless project execution.

SONGS and Underwater Construction Company (UCC), the diving subcontractor on the Westinghouse-led project, used traditional predictive techniques to plan the replacement of the thimble rods in SONGS Units 2 and 3. In actual physical trials used to plan the work, divers sat on the moveable chair mechanism that would be used to position them to cut the thimble rods. During the trials, planners measured variables such as the torque required to make each cut, the best position for storing the cutting tool between cuts, and the overall time required.

As work on Unit 2 began, SONGS technicians modeled many of these same variables in parallel using process simulation software, and the results were compared with those obtained in the actual physical mockups. "We actually didn't know what SONGS was doing at the time, but they came to us on several occasions with suggestions for improvements," remembers Charlie Vallance, UCC's general manager for technical services. "We kept wondering how they were coming up with these ideas. We only found out later that it was from the modeling they were doing with PLM."

For example, Vallance said, the original plan called for the diver to store the cutting tool in a pocket located beneath the chair. But the virtual simulation showed that the divers' suits would make it difficult for them to reach the tool. SONGS technicians recommended that UCC workers simply lower the tool to the diver once he was in the water, eliminating the difficulty.





The thimble and moon pool simulation within the context of the station structure

Simulations less costly

"I'm very impressed by what I've seen of the simulation and modeling software," Vallance said. "It's early yet, and the nuclear industry is a bit behind the curve on adopting this technology, but I think it will become an industry standard. We still do our estimating for cost and radiological exposure on spreadsheets," he continued. "It's slow and time-consuming and requires countless checks to ensure that you have covered all your bases. PLM is undoubtedly a better process, because with the software, the schedule can drive the simulation or the simulation can drive the schedule. It's very powerful."

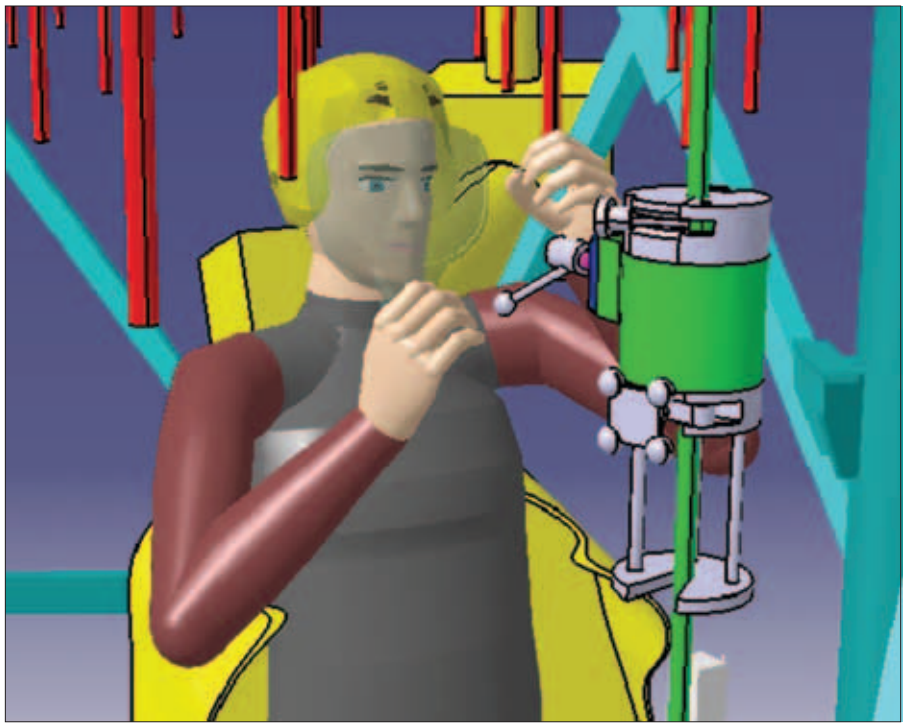
Today, Vallance said, companies like UCC get the information they need to plan complex projects by conducting actual trial operations. "Compared to a PLM strategy, the way we do things now is relatively crude," he said. "The physical mockup or demonstration of the whole process is planned to be as accurate as possible, but it's never exactly like what we encounter on the real project. Often we find the mockup only vaguely simulates what's going to happen. In some cases, things drastically change as a result of the mockup, but there's no opportunity to do it again. It's too expensive."

Vallance said UCC invested "hundreds of thousands of dollars just on the mockup of the thimble rod project. And you can't reuse what you learn from one job to the next because every plant is unique. With

software that would allow us to simulate digitally, we could run the simulation repeatedly to check different processes at very little incremental cost. We could eliminate things that don't work long before we get to the physical mockup stage. We could identify the most efficient processes, which could cut the time and cost of a project. If you can save 20 minutes on an operation that's going to be repeated hundreds of times, it adds up."

PLM software also automatically calculates and tracks not only financial budgets, but dose budgets that measure the radiation exposure of divers. "You never want to exceed the dose budget," Vallance said. "One of the complications with radiation is that the amount of exposure a diver gets is determined not just by time but by body position. A few inches can make a big difference. Simulation software could track all of those variables so you know in advance how to minimize the exposure and where you stand on the dose budget at any given point in a project."

The simulations conducted on the thimble rod project marked the first application of PLM to nuclear plant operations, and the tests demonstrated that as much data could be gathered virtually using PLM software as in actual practice, even underwater. The PLM simulations even identified some gaps in the work process that were overlooked in actual physical mockups. This allowed processes to be revised to take advantage of lessons learned from the PLM simulations while the work continued.



Simulated diver begins cutting thimble rods. Clash analysis and radiation exposure are part of the human/reactor pool simulation factors incorporated into the software.

PLM overcomes challenges

One of the first challenges SONGS must overcome in its steam generator replacement project involves moving the genera-

tors from the ships that will deliver them from Mitsubishi's manufacturing facility in Japan to the SONGS plant on the California coast midway between Los Angeles and San Diego. The initial plan involves bringing the generators into the port of Long Beach, where they will be transferred to barges for the 60-mile trip down the coast to the Camp Pendleton Boat Basin, in Oceanside, which is operated by the U.S. Marine Corps. From there, the generators likely will be moved the 16 miles up the coast to the plant via a specially designed transport vehicle, although highway and inland options exist as well.

Steve Kenney is manager of business development for Bigge Power Constructors, one of the companies bidding on the transportation portion of the project. Like UCC and most nuclear industry contractors, Bigge uses spreadsheets to plan its procedures for moving nuclear plant equipment such as the steam generators. Kenney believes that the adoption of PLM would make the process significantly easier and more accurate.

"There's great potential for it," Kenney said. "Today, the industry has to use drawings—cartoons, really—to illustrate the process, but it's not real. There are no dimensions, no correlation between the physical world and what's being shown in the drawing. But with PLM, everything is modeled—the actual physical dimension, the weights, the properties, the structural capacity of the floor, the capacity of the cranes, the stresses as the loads shift, and on and on."

With a PLM process, Kenney said, companies like Bigge could prove to their utility clients and lead contractors that the processes and procedures they propose will work, and they could demonstrate their proofs visually, as well as mathematically. "Today you prove it with pieces of paper stamped by engineers," he said. "But if you can show the customer what you're going to do physically, with real substance in a virtual environment, it will carry a lot of weight. It's going to ease minds, because the last thing the nuclear business can afford to do right now, when we're looking at life extensions for existing plants and plans to build new ones, is to make a mistake. The responsibility to get everything right is enormous."

With accurate virtual mockups, Kenney said, contractors can write more accurate procedures, eliminating the potential for unexpected snags. "Say you're going to move a steam generator through the plant and you have to take a turn or make a change in elevation. The guys who are writing the procedures can see that as it happens on the screen, and they can write detailed procedures based on what they've seen. You don't want to find yourself rewriting the procedures on site because you missed something, but it happens. If you test everything with the software, you'll eliminate those headaches where something was missed or something has to change."

Kenney anticipates that widespread adoption of PLM in the nuclear industry will cut the time and staff required to make plans and write procedures, helping to quickly recoup the cost of the software. "The longer an outage takes, the more it costs," he said. "If we have software that makes the process easier and faster, with fewer people, we will reduce the costs."

Kenney said he sees as much potential for the software in building new plants as in retrofitting existing ones. "To model a new plant in 3-D from the beginning would be extremely helpful," he said. "You have as-built drawings today, but often the plant isn't actually built that way, or it has been modified somewhere along the line and the two sets of plans have not been consolidated. With an electronic 3-D model, you could have access to a plan of the plant as built and every change made along the way. When you go into an outage, it will shorten the work time. It will be cost-effective and simplify the operators' processes. Having everything modeled virtually would change the entire dynamic."

Benefits being realized

The PLM process has already been applied to the steam generator project at SONGS. Mockup capabilities were used to verify the equipment designs developed by Mitsubishi through the use of more traditional, paper-based methods. Most contractors in the industry still use these traditional methods, and PLM allows SONGS to verify contractors' proposals quickly and affordably.

Taking a cue from aerospace and automotive companies, SONGS has also used models and simulations for training, allowing workers to "see" in advance the procedures they will carry out during an actual project. The simulations allow workers to learn what to expect and to do their work more efficiently because they have already walked through a simulation of the job.

The PLM process also allows SONGS to test different scenarios. The plant refuels every 20 months, and that is enough time for workers to forget lessons learned on the previous refueling. With the simulation software, SONGS can capture those lessons from one outage and use them again during the next outage. Time and motion studies performed in virtual 3-D on standard outage tasks also allow SONGS to identify the most efficient procedures possible, saving time and money.

Officials at SONGS see PLM as a critical strategic process that enhances the plant's ability to perform one-of-a-kind projects efficiently, cost-effectively, and, most important of all, safely. NN