

A simulated image of the reactor coolant pump motor inside the Waterford-3 containment building. The motor is about 10 feet in diameter and about 20 feet tall, and weighs about 57 tons. (Graphics: Entergy Nuclear, BCP Engineering & Consultants, and Dassault Systèmes)

OUTAGE PLANNING

3-D software, laser scanning used to prepare for refueling outage at Waterford-3

ENTERGY NUCLEAR USED digital modeling and virtual simulation to prepare for the 17th refueling outage (RFO17) and a reactor coolant pump (RCP) motor changeout at the Waterford-3 nuclear power plant in Taft, La. The plant, which started commercial operation in September 1985, is an 1173-MWe Combustion Engineering pressurized water reactor. The outage started in October.

The potential return on investment from using the digital tools is 20 to 1, according to John Mahoney, innovations leader for Entergy Corporation. Mahoney noted that each day a nuclear plant is out of service, about \$1 million in replacement power must be purchased.

In addition to the refueling and the RCP

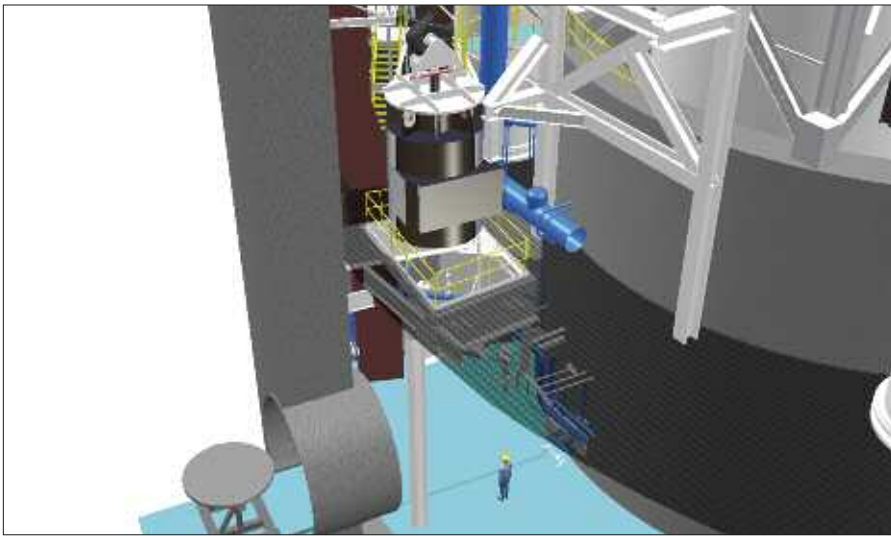
Digital modeling, virtual simulation, and in-containment scanning helped prepare for the refueling and maintenance outage at Waterford-3.

motor replacement, outage work was to include inspecting the reactor vessel head and steam generator tubes and replacing in-core instrumentation (ICI) sensors and thimbles. BCP Engineers & Consultants, of Gretna, La., was the prime contractor for the outage.

To prepare for the outage, containment-building scanning was performed by Areva NP, of Lynchburg, Va., to make sure that the RCP motor could be moved safely in and out of containment. Scanning refers to the use of

lasers and other devices, such as white-light systems, to collect precise geometric data—sizes, shapes, and clearances—on the plant as built and as maintained. Clearances for moving some large components, such as steam generators, could be as tight as two inches. “This means precise laser measurements and a 360-degree view are essential,” Mahoney said.

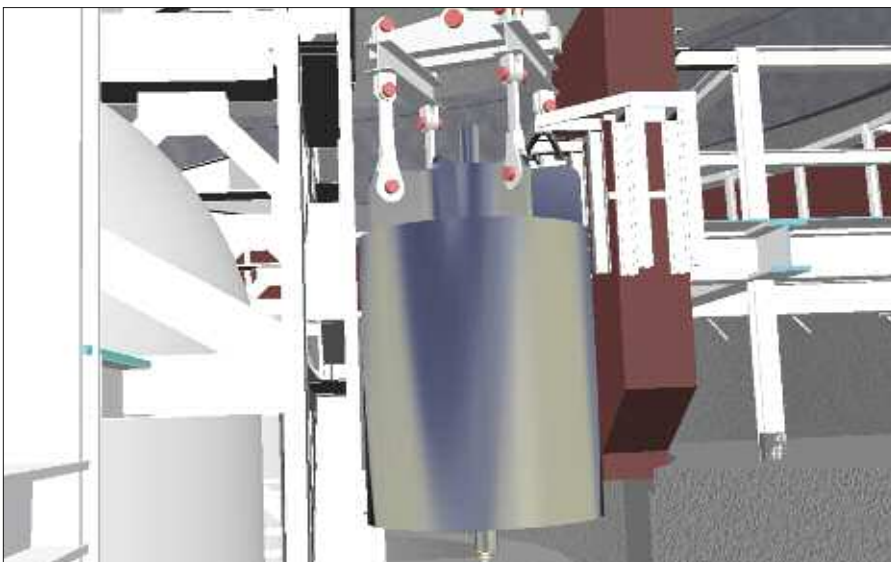
Scanning is not new in the nuclear industry, but it is not widespread, according to Mahoney. Modeling and simulation have



The motor will be lowered to the floor of the containment building and will be removed through the cylindrical port (at lower left). The installation of the replacement motor will follow the same path in reverse.



The beam structure between the two figures in yellow hard hats is one of two interferences detected by modeling and simulation during preparations to remove the RCP motor.



A side view of the RCP motor lift showing the second potential clearance problem in the containment building—the angled steel structure just to the right of the hoist.

also seen sporadic use. Instead, full-sized component mock-ups have traditionally been employed for worker practice before actual outage work begins. Leading up to RFO17, Waterford-3 used an RCP motor mock-up to prepare for the work.

Mahoney predicted, however, that the high cost of the mock-ups—hundreds of thousands of dollars apiece—“would be a major factor driving the use of 3-D virtualization.” He added that mock-ups do not readily accommodate engineering changes and plant modifications, nor are they easily modified for reuse in other facilities.

Gerald Butts, a Waterford-3 project manager, concurred. “A sheet-metal mock-up of the RCP motor was made and moved in and out of containment,” he said. “But the necessary comfort level of really being able to move the motor was not reached. The 3-D modeling and simulation gave us an extra [reassurance] factor we had to have to start the project.”

As part of the pre-outage planning process, Waterford-3 used modeling software from Catia and 3-D simulation software from Delmia. Both product lines are owned by Dassault Systèmes, of Paris, France. Mahoney said that use of the digital tools would result in the completion of maintenance tasks more expeditiously during the outage, thereby shortening the time until the plant could go back on line. Also, any potential delays, if discovered during the pre-outage phase, could be avoided, keeping costs and scheduling impacts down.

The value of modeling and simulation, Mahoney said, lies in “their ability to ‘virtualize’ and ‘visualize’ a proposed modification to a plant. These technologies add new and unique opportunities to review options and ‘see’ the effects of the change virtually.”

This can be done, he said, “while we are planning construction activities and conducting pre-job briefings. Even when a simulation reveals no problems, it still has huge value.” Some examples, he said, are as follows:

- Plant employees and craftspeople are trained better and sooner, and everyone understands the work and his or her role in it.
- 3-D virtual simulations can augment, if not entirely replace, verbal explanations and paper drawings. A reduction in human errors is assured, according to Mahoney.
- Coordination among all the crafts and contractors on site is improved. The 3-D “virtual tours” analyze task sequences, work practices, and tool selections before anyone enters the containment building. Better project execution results.
- Knowledge retention and transfer help offset retirements from the workforce.
- New engineering ideas and alternative solutions are evaluated more quickly and at far less cost than by trial and error.

For Waterford-3’s pre-outage planning,



Out in the real world, an RCP motor similar to the one in Waterford-3's project is being prepared for loading on a flatbed truck for transport to a shop for refurbishing.

Entergy ran the following simulations using the digital tools:

- Analysis of the impact of a potential fire on equipment located in a key area of the plant.

- A run-through of the RCP motor replacement. The pump is one of four that circulates the heated water in the reactor, providing steam through heat exchangers to drive the plant's steam generators. The RCP

motor is rated at 9700 horsepower and weighs 115 000 pounds (more than 57 tons). The RCP work was expected to take 25 days during the outage.

- Replacement of thimbles and ICI sensors that monitor reactor fuel. ICI sensor replacement requires divers to work underwater in an area close to irradiated reactor components as they cut out old units and install new ones. The simulation focused on ergonomics and radiation-exposure monitoring, Mahoney said.

Mahoney noted the bottom-line benefits of using the digital tools: optimized engineering designs, more efficient planning, tighter inventories, reduced supply-chain requirements, and a reduction in unforeseen needs to bring in vendors and contractors.

Entergy was also evaluating several digital simulation options that combine programs for radiation worker protection, outage scenario planning, and physical security, according to Mahoney. Other simulation programs being assessed include 3-D document management and configuration management for future plants. The utility is also looking at developing operational and engineering databases with 3-D tools, starting with Waterford-3, to track and manage all plant changes. For now, the plant—as it was designed, as it was built, and as it has been maintained—is being documented with a digital life-cycle management program. ■

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