Oconee upgrades to digital turbine controls

Digital machine controls have helped Duke Power maintain reliable performance through fault-tolerant operation, increased automation, and greater process visualization.

When many of the nation's nuclear power plants were commissioned some 30 years ago, analog control systems were the state of the art in ensuring plant reliability. These analog systems, however, presented certain constraints. For example, when one component failed through normal wear and tear, the entire system would have to be shut down, adding risk and costing hundreds of thousands of dollars a day in downtime.

Duke Power's Oconee nuclear power plant, in Seneca, S.C., is undertaking a program to replace its older analog turbomachinery controls with new digital systems. The plant has three Babcock & Wilcox pressurized water reactors. Unit 1 started commercial operation in July 1973, Unit 2 in September 1974, and Unit 3 in December 1974. The units are each rated at 846 MWe.

The replacement job was performed at Oconee's Unit 1 in 2004, and similar work was done at Unit 3 earlier this year. Unit 2 is scheduled to undergo the process this fall.

Marlon Dempsey, an instrumentation and controls engineer at Oconee, said the old analog turbine control systems were one of the top three causes of trips and transients at the plant, primarily because their components presented a single point of failure. "We knew that introducing more redundancy at key points would enhance reliability considerably and found that digital technology could provide that redundancy while at the same time reducing the cost of downtime," he said. "If a trip causes a shutdown for an entire day, it could cost us as much as $250 000 for that day."

Before the replacement program started last year, plant engineers evaluated several turbomachinery control options and decided on a fault-tolerant system that features triple modular redundancy (TMR) architecture. The new system that Oconee decided on—the Tricon digital system, from the Triconex unit of Invensys Process Systems, of Irvine, Calif.—eliminates single-point failure vulnerability within the turbine controls.

TMR architecture uses three isolated, parallel control systems and extensive diagnostics integrated into one system, according to Dempsey. It employs two-out-of-three voting to provide high-integrity, error-free, uninterrupted process operation with no single point of failure (see box, page 52).

"Not only is the controller triple-redundant, but where possible, we also made critical field inputs triple-redundant," Dempsey said. "This level of redundancy is

A newly digitized control room at Duke Power's Oconee nuclear power plant replaced dated analog hard-panel interfaces. (Photos: Marlon Dempsey/Oconee)

typically found in nuclear safety–related systems, but not in older analog control systems. When you consider that the turbine can trip the entire plant, it makes sense to go for the highest quality system."

Oconee management also wanted an easier-to-use alternative to the analog system's hard-panel interface, with its various switches and meters that made running manual tests and acquiring readings somewhat tedious. In contrast, the new digital system is easier to use, according to Dempsey. The new system replaces switches and meters with a touch-screen user interface and other technical features and capabilities, and it also controls such variables as turbine speed and valve operation through its communication with field sensors. In addition, it automates the quarterly turbine-valve movement tests and the monthly trip tests that ensure the turbine will trip when necessary to protect the system. These tests previously had been performed manually.

Cabinet and wiring

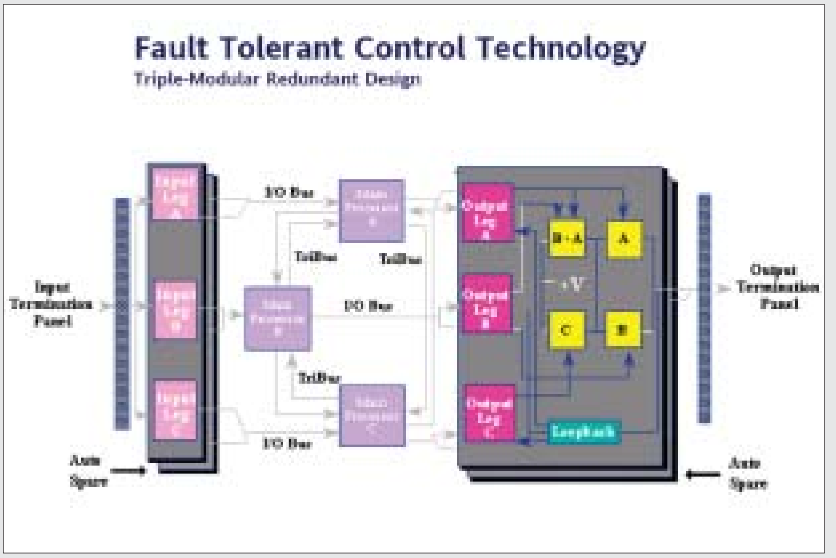
The cost of the project was reduced by eliminating the need for new cabinets and cabling, Dempsey noted. This was made possible through some pre-installation work done by Triconex, whose technicians mounted a new system inside a mock cabinet that matched the dimensions and available space of a cabinet in a "cable spreading room" at Oconee. Once on site, the new system was transferred from the simulated cabinet to the actual cabinet. "[Triconex technicians] used our existing wiring cabinets, where there was very little maneuvering room, and they solved this by performing extra design work up front," said Dempsey, who added that Oconee's existing cabling was in good condition and in no need of replacement. "Installing a whole new cabinet and pulling all new wires would have been both expensive and time consuming." Of added benefit was the fact that installing the new equipment into the existing cabinets saved the effort of moving the whole operation to a new location.

Improved control design

The logic in the plant's old analog system was derived from individual circuit cards that took about a week to calibrate. With the new digital system, however,

How triple-modular redundancy works

The TRICON digital system's triple-modular redundant architecture employs three isolated, parallel control systems and extensive diagnostics integrated into one system. The TRICON appears to the user as one set of hardware, not three, allowing one control program for the application logic to be developed and downloaded to the three main processors. Extensive diagnostics manage internal system coordination without application program support. The system uses "majority voting" to provide high-integrity, error-free, uninterrupted process operation with no single point of failure. Should any one of the three control components fail, the TRICON system continues correct operation without any process interruption. The locations of failed components are annunciated, allowing maintenance personnel to replace the failed component while the system continues control of the process.



Oconee personnel don't have to calibrate at all. "Because of the digital logic, we've essentially eliminated this task," said Dempsey. "Now we just verify that the version of logic running in the machine matches a controlled copy, which frees up a lot of time to allow personnel to do other work."

The new digital system also eliminates the need to call in outside vendors to make logic changes. "We have more control to modify the logic design of the system to match the needs of our plant," he said. "Our old analog system did not allow for changes because it was hard-wired. With the digital control system, we can easily make enhancements."

Dempsey said that Oconee's engineering team has already used the new system to automate turbine chest and shell warming during startup, freeing operators from the task of sitting at the controls and running the process manually. The engineers have also used the controls to improve valve movement testing, implementing a "feed-for-

Oconee upgraded to a digital control system for its turbine machinery.

ward" control strategy, in addition to the traditional first-stage pressure feedback methodology, he said.

"With a feedback methodology, the control system would have to wait for a transient to occur and then react, but the TRICON allows us to implement a feed-forward system to anticipate the steam loss based on valve position and react, which minimizes the overall effect ahead of time," he said.

Process visibility

To enable Oconee's operators to interact with the controls more effectively, the new digital system came with Invensys Process System's Wonderware InTouch human-machine interface software. Where operators previously viewed the control system through a hard-panel interface, they now have a graphical user interface that provides much more information than they had before, said Dempsey.

The software enables operators to execute startup and valve tests much more efficiently than with an analog system. In constant communication with the controller, the software first confirms whether it is safe to run a specified test, and then automatically runs the test and reports on the results. If any failures occur, the software tells the operator where and why the failure occurred. The system will also abort a test if a condition arises that will affect system performance or safety. The visual touch-screens help by telling system operators what is wrong when something happens, along with ample diagnostic information.

"With the old system, we would know when a problem occurred, but we wouldn't always know exactly what caused it," Dempsey said. "This system makes it a lot easier for our technicians to locate the source of problems."

To take full advantage of the new automation platform, Oconee is also considering extending digital control to other systems, such as the feedwater system. NN