# Duke upgrades to digital I&C at Oconee

*Oconee-1 is the first U.S. power reactor to employ digital instrumentation and controls for a substantial portion of its safety-related systems.*

The upgrade to digital I&C at Oconee-1 involved extensive disconnection from the original analog equipment and reconnection to equipment in new cabinets.

Duke Energy's Oconee-1 is now more than half a year into the use of digital instrumentation and controls for its reactor protection system (RPS) and engineered safeguards protection system (ESPS). The same upgrade, based on Areva's Teleperm XS system, will be installed on Unit 3 next year, and on Unit 2 the year after that. This is the most extensive conversion yet to digital I&C for any operating power reactor in the United States, all 104 of which were designed and built with analog I&C equipment that has become increasingly difficult to maintain or replace.

This article on the Oconee conversion begins with observations from Duke Energy, which sent *Nuclear News* the following report.

## Plant staff perspective

When it came on line in the summer of 1973, the Oconee nuclear station, in Seneca, S.C., was one of the nation's first nuclear power plants to begin commercial operation. Years later, it became the nation's first nuclear station to generate more than 500 million megawatt-hours of electricity. In 2011, the plant is completing two more firsts. The station is undertaking major upgrades to its RPS and ESPS and is piloting a new fire protection program.

The RPS/ESPS upgrades were implemented on Unit 1 during the plant's spring refueling outage, making Oconee the first plant in the nation to move these systems from analog to digital. Units 2 and 3 will receive the upgrades during the next two years. While the operators' interaction with the new system isn't drastically different, the modifications further enhance the safety and reliability of an already safe plant.

With the exception of a few extra indicator lights and digital readouts, the new system looks and feels the same as the old one. Behind the scenes though, in cabinets full of computer equipment and large mazes of strategically placed wiring, the "guts" of the system provide real-time assessments and calculations on a number of important parameters.

On a continuous basis, the reactor protection system monitors inputs such as core power and reactor coolant system temperature and pressure, while the engineered safeguards protection system monitors pressure changes in the reactor coolant system and reactor building. If any condition monitored by the systems approaches a limit point, the RPS/ESPS system can automatically trip the reactor or activate key systems that will mitigate the situation.

On the flip side, the system also knows when to exclude inaccurate information. In other words, if one of the plant's many backup sensors fails, the new system will automatically exclude the bad sensor and won't use it to make decisions for the plant. This prevents reactor trips and further improves plant reliability.

The upgrade has been a large undertaking for Oconee, which planned an extended refueling outage for Unit 1 to accommodate the work. The Teleperm XS system costs $250 million.

"As the first plant in the nation to add this new equipment, Oconee is demonstrating its commitment to continuous improvement as new systems and technologies become available," said Oconee Site Vice President Preston Gillespie. "It's enhancements like these that have us well positioned to operate a safe, reliable, efficient plant through the duration of our license extension."

With two more units to upgrade between now and 2013, the project work isn't yet complete, and the site management knows the industry is watching.

"Our plans went through an extensive approval process with the Nuclear Regulatory Commission, and we want to be an in-

The I&C upgrade has been finished at Oconee's Unit 1 (left). Unit 3 (right) will be upgraded in 2012, and Unit 2 (center) in 2013.

dustry leader for this important work," Gillespie said. "The system has worked extremely well since Unit 1 came back to full power, and we look forward to completing the upgrades on the other two units in future refueling outages."

Continuously improving is something that's embedded in the culture of Oconee. When the Nuclear Regulatory Commission sought pilot participants for its new fire protection guidelines (National Fire Protection Association Standard 805, a risk-informed and performance-based alternative to the prescriptive requirements in the NRC's original regulations), Oconee joined one other plant in the nation in helping build the foundation for the new program. For five years, Oconee and its parent company, Duke Energy, have been working toward a January 1, 2013, implementation date. When the new guidelines go live, Oconee and Progress Energy's Harris nuclear plant, near Raleigh, N.C., will have implemented a new risk-informed, performance-based approach to fire protection.

"Essentially, NFPA 805 will allow us to customize our fire protection strategies, focusing on where fires are most likely to occur and how large they could grow based on the source and location," said Duke Energy's NFPA 805 Technical Manager David Goforth. "Because we now analyze our plant using realistic fire evaluations and apply the element of risk to that fire, we can identify where our real risk locations are and mitigate the effects of the fire. This new method further improves our safety margins."

## Duke, Areva, and the NRC

With thanks to Duke, we now shift the focus somewhat to include the supplier and the regulator. While Oconee is now through essentially all of the approval processes for both the digital I&C upgrade and the adoption of NFPA 805, working on both at the same time turned out to be a bigger challenge than Duke had expected (as company representatives have stated in public venues). Duke, Areva, and the NRC had many prolonged discussions during the technical reviews of the license amendment request and the deployment of the Teleperm XS system. Now, at least, Duke can realize the benefits of the system upgrade on Unit 1 and, through the inevitable learning of lessons, look for a smoother transition during the installation work on Units 3 and 2.

Several presentations on Duke's digital I&C installation were made during the ANS 2011 Utility Working Conference in August. The following reportage is based on those presentations, in which Duke, Areva, and the NRC each had its say. (Further coverage of the UWC can be found on pages 81 through 96 of the October issue of *NN*.)

The digital version of the RPS/ESPS uses the existing sensor inputs for reactor protection and accident mitigation and actuates the existing reactor trip breakers and engineered safety feature systems and components. The new system also adds diverse actuation systems for low-pressure and high-pressure injection.

After considerable preparation, Duke submitted its license amendment request to the NRC in January 2008. Things did not go very smoothly during the agency's reviews, but the amendment was granted two years later, with a safety evaluation report that called for reviews of four software plans (maintenance, operation, training, and installation) and a site acceptance testing plan, plus 40 inspector follow-up items in areas that included documentation of modifications and the design basis; installed configuration; review of procedures for operations, maintenance, and cybersecurity; the operations manual; software training; and system indications and alarms.

The NRC's areas of concern, formulated during the acceptance review for the amendment request, included the assessment of diversity and defense-in-depth (referred to as D3); bidirectional communications between safety and nonsafety systems; the software quality program; the acceptability of hardware, software, and procedure changes; compliance with IEEE Standard 1012 on software verification and validation (V&V); and software test tool questions.

Key documents that Duke provided to the NRC in the course of the reviews covered commercial-grade dedication plans; D3 analysis; system description; hardware and software architecture; system requirement specifications; software V&V plans; a requirements traceability matrix; failure modes and effects analysis; configuration management plans and procedures; software design; factory acceptance test plans, procedures, and report; software installation and safety plans; equipment qualification test reports; uncertainty calculations; and the site acceptance test plan.

The new system for Unit 1 was finally installed in April and May of 2011. The major activities included isolation of the RPS and ESPS; determination of the extent of the existing analog system; removal of the analog system cabinets; removal of fire penetration material; placement of the new system cabinets in the control room; connection of the cabinet circuitry; system power-up and calibration; restoration of RPS and ESPS equipment; and functional, integrated, and startup tests.

With Teleperm XS installed on Unit 1, Duke and Areva have moved on to preparations for the other reactors. The cabinets for Unit 3 have been assembled at the plant site, and work was ongoing on cabinet assembly for Unit 2. From Areva's standpoint, the Unit 1 installation process was an opportunity to see how Teleperm XS would be received by a customer and assessed by a regulator. Areva said that it learned lessons in areas such as design changes required before the start of the outage, preparation for the outage by crews and staff, "war room" setup and staffing, craft skills, project execution, legacy issues, and testing.

NRC oversight of the project included five separate audits and weekly status meetings. Inspection activities included an operating procedures review, a surveillance test procedures review (to ensure that the system remained operable during test evolutions), confirmation of the usage requirements for key switches, and confirmation that physical security measures had been put in place.

Issues with the new system's operational methods were identified during simulator training, system testing, and procedure development activities. It was found that the use of diverse actuation systems to address common cause failure can change the way the systems should be operated, showing the importance of simulation testing, analysis of accident scenarios to validate operational characteristics, and operator training to confirm system responses to operator actions. In regard to surveillance testing, the NRC stated that the requirements for performing on-line tests while maintaining protection system functionality were not considered fully during system design, and this was not discovered during the safety evaluation because surveillance procedures were not available to the NRC at that time.

The NRC also found issues in installation and startup, such as tagging, de-energization, repurposing and reuse of cables, and refueling activities taking place during system replacement. The NRC noted that there can be peripheral aspects to extensive modifications, even in areas where the design is not being altered.

Now, as Duke finishes the upgrades on the other two units and operating experience accumulates with the new system, it is time for other reactor owners to decide how to proceed. As Bradshaw noted, the industry has been watching Oconee. With analog I&C obsolescence sure to increase, the question is probably not whether to convert to digital I&C, but how soon, and to what extent. NN