Dominion makes strides in nuclear station transformer and switchyard reliability

BY RICHARD ZUERCHER

A company initiative identifies and replaces aging components—such as generator step-up transformers and transmission breakers—before they fail.

A RECENT CHALLENGE IN the nuclear power industry has been the drive to sustain uninterrupted baseload operations through improved transformer and switchyard reliability. Dominion, through a company initiative, has elevated transformer and switchyard care and maintenance at its nuclear stations to a higher, "nuclear-grade" standard.

Dominion operates six nuclear reactors: the two-unit North Anna power station, in Mineral, Va.; the two-unit Surry power station, in Gravel Neck, Va.; and the two-unit Millstone power station, in Waterford, Conn. (A third unit at Millstone was retired in August 1998.) All six units are pressurized water reactors.

Dominion found that on the electric transmission and delivery (T&D) side of its business, major and minor components were reaching the end of their design lives and were starting to fail. A company analysis found that many components had clearly defined lifetimes that determined when they needed to be replaced. The company responded with a program to identify and replace components before they failed. This program is aggressive in planning the replacement of generator step-up transformers, transmission breakers, coupling

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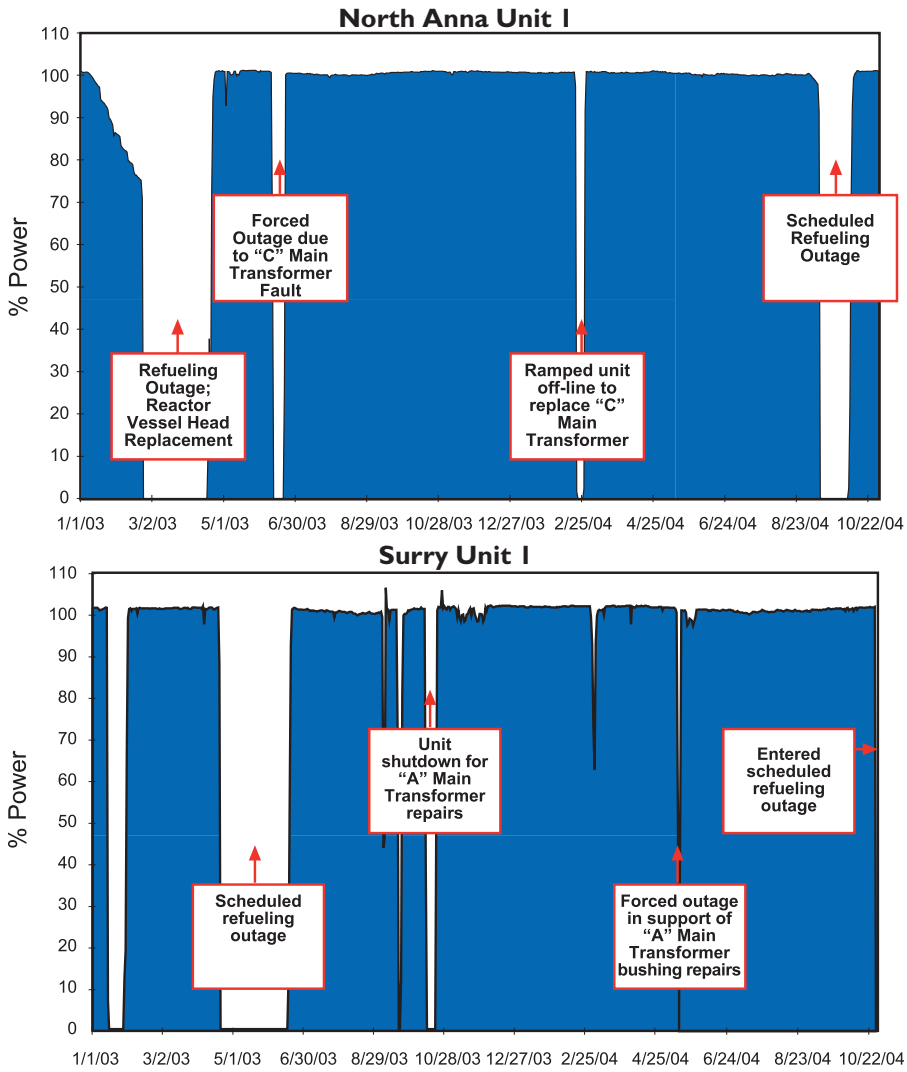

Power histories of two of Dominion's nuclear units, January 1, 2003—October 31, 2004

Two new generator step-up transformers are barged from Hampton Roads, Va., to the Surry nuclear power station in Gravel Neck, Va. (Photos: Dominion)

capacitor potential devices, and other minor equipment before they fail.

A review of how transformer and switchyard maintenance was performed revealed that the company's approach to buying components to maintain a stable and efficient electric delivery system was not rigorous enough to meet the reliability demands of the nuclear power stations, said David Roop, director of electric transmission operations for Dominion. Typically, he said, the component reliability requirements for the electric distribution system are not the same as for the nuclear stations, which are run 24 hours a day, seven days a week, for 18-month cycles, and have one path to the grid. This T&D equipment is further stressed by increased service hours due to the improved performance over the past decade in nuclear plant run-time. This improved performance has exposed these components to more heat, additional voltage stresses, and abnormal events that have reduced their anticipated life expectancy.

Dominion reached this conclusion after several main station transformers—some of them relatively new—had to be replaced at North Anna and Surry because of premature degradation. Further, a catastrophic failure of a coupling capacitor on a 500-kV transformer at Surry in May 2004, which resulted in operators' having to remove Surry-2 from service to fix the problem, brought to the forefront the importance of requiring higher standards for switchyard components.

Two years ago, Dominion began its program to identify areas for improvement in its T&D equipment and other business units. This has included ensuring that components meet more stringent reliability and warranty requirements.

Single-point vulnerability

At Surry and North Anna, Dominion performed single-point vulnerability analyses of all electrical components to determine if they were reliable, or whether a maintenance and replacement program was necessary. Plans are now being developed to replace components and to perform a similar analysis at the Millstone power station.

As part of the analyses, the company segregated the nuclear stations into "electrical zones" to effectively evaluate and develop maintenance programs. For example, if the generator zone at a plant had a problem, the generating capability of the plant might be lost. Or, if a problem arose in the electrical bus zone, it could affect the reliability of plant safety and support systems. As a company, Dominion needed to understand these zones and have a better knowledge of the electrical components in them. This, then, would facilitate a change in maintenance program requirements or replacement criteria, given the function or criticality of the equipment.

Looking specifically at switchyard issues, Dominion found that the Surry and Millstone switchyards are susceptible to salt spray, because Surry is cooled by water from the brackish James River and Millstone from the Long Island Sound. These switchyards require more maintenance than North Anna's switchyard, which draws its cooling water from a freshwater lake in central Virginia and is not subjected to salt spray.

To address salt spray issues, Dominion specified that extended creep insulators be installed in replacement stress cones on new underground cable at Surry. The company also recommended replacing critical bus zone low-voltage insulators with a polymer design that is less susceptible to salt contamination. This design change is a result of insulator testing that Dominion performed on the Outer Banks of North Carolina using various insulators, coatings, and configurations in an effort to improve the performance of substation equipment in salt-contaminated environments.

Also, when Dominion tested electrical equipment at the switchyards, it found discrepancies in the criteria used to determine whether a component needed to be replaced immediately or could remain in service a while longer.

The company realized that the decisions made on component replacement needed to take into account the fact that a nuclear unit is expected to operate continuously for 18 months. Therefore, if an electrical component showed signs of degradation, an analysis needed to be performed to determine whether it could be expected to operate in a degraded condition for 18 additional months. With that in mind, another review process was established to ensure that marginal equipment was being examined and replaced if necessary.

The transformers are then unloaded from the barge on the James River near Surry's intake canal.

Genesis of the problem

When switchyard and T&D-related problems began emerging, the company was segregated not only by business function, but also culturally, meaning that the generation side of the business was focused on operations, for example, and the T&D business was more focused on cost and service.

Professionals on the electric delivery side were accomplished at developing low-cost engineering designs for components used to deliver electricity to the company's customers. But reliability standards for T&D components used for electric delivery are not as high as for those on the nuclear generation side due to the ability to serve these customers from multiple sources if a failure were to occur.

Part of the problem was an ownership issue. The nuclear stations looked at the switchyards as part of the T&D business, but the electric delivery side viewed the switchyards as part of station operations. So, while the company had changed organizationally, transformer and switchyard ownership expectations had not.

Dominion also found that when its Nuclear Business Unit (NBU) assigned an electrical delivery supervisor to review industry operating experience or industry reports, that supervisor would contact a counterpart in T&D for advice, and then respond accordingly. No one in a higher position in T&D was looking at whether business changes were necessary to address these issues. Things changed so that now a higher-level review is required to ensure that these issues are addressed appropriately.

For years, Dominion has had substation supervisors, who oversee the switchyards' protective relays, physically located at Surry and North Anna. These supervisors provide a "one-stop shop" to alert the T&D business about any items that are a concern. There was a need, however, to provide the stations with a technical advisor who could interface with the NBU to ask questions, such as, "Are we providing the right component for the specific application?" The company has since provided this additional function.

Another area strengthened to improve reliability is component testing at the manufacturing facility. The company is requiring vendors to conduct more stringent testing of electrical components that will be used to replace aging counterparts to ensure that they will perform their intended function over their projected operating lives.

"What we are now seeing is a strong recognition by everyone that there are different degrees of adequate reliability," Roop said. "If I'm installing underground cable for a residential neighborhood, I can put it in and move on. But if I'm providing this service for a nuclear station, it will be tested first to make sure it will provide the reliability needed."

Retaining knowledge

One thing that has helped Dominion over the years with its generator step-up transformers has been the retention of its transformer experts and design engineers. That is important for reliability because Dominion requires a design review of all step-up transformers.

"I believe we are the only company in the industry that thoroughly tests every transformer before it comes to a plant," said Roop. "As a result, we are seeing a lot more failures during testing—which is the time we want to see failures, rather than when the equipment has been delivered and already installed at our stations."

In testing the transformers, the company also ensures that the components can take greater-than-normal stresses. In that regard, Dominion requires a 125 percent overload heat run test, since these components will operate at 100 percent capacity over hot summers.

Dominion believes it is an industry leader in the way it has responded to transformer and switchyard reliability issues. An aggressive approach and implementation of higher standards at the company's nuclear stations will help resolve the reliability problems of the past and, possibly, set the benchmark standard in the industry.

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Left: Lockwood Brothers, the load hauler, transports one of the transformers into the Surry station.
Below: The transformers are then assembled by Surry electricians.
Bottom left: Surry lead system protection technician David Logan installs new relay systems for transmission line protection at the station.
Bottom right: Logan checks tags in the potential make-up box for new couple capacity potential devices.

Tim Marshall, senior system protection technician at Surry, checks the fan and cooling controls on one of the new transformers.

Industry partnering

Dominion recently approached the Southeastern Electric Reliability Council (SERC) to propose the development of a task force to address the communication and grid reliability impact on nuclear stations. The SERC members endorsed this proposal and the task force—named the Transmission–Nuclear Interface Task Team—is beginning this important work.

The stated purpose of the team is to "enhance the safe and reliable operations of the interconnected transmission grid through a focus on the unique operating requirements of nuclear power plants." This group will work in collaboration with the Institute of Nuclear Power Operations to ensure that their mutual efforts will provide the maximum benefits to assist the industry in addressing the grid operator–nuclear station interface issue that it now faces.

"This is a significant step forward for grid reliability," said Roop. "In all, seven transmission owners that have 19 nuclear generating facilities on their systems in the Southeast have joined together to work in collaboration on this problem. As an industry, I think we are taking the right approach and putting the necessary resources on this problem to resolve it." NN

Relay technicians look at new Mitsubishi 230-kV circuit breakers that are being installed in the Surry switchyard to enhance reliability.