Precision measurement for nuclear power

Application Note

Testing Functions
Case Study

Tools: Fluke precision multimeters and handheld multimeters

Tester: Cory Peters, Calibration Lab Supervisor and Chief Metrologist at Exelon PowerLabs

Tests: Milli-Amp tests with a low resistance meter to certify sensor performance; monitoring voltage supply with high impedance meters; using min-max to pinpoint actuation on relays

In the early morning hours of March 28, 1979, the U.S. nuclear industry's worst accident occurred at Three Mile Island. A combination of equipment faults, poor instrumentation and human error led to a partial meltdown and the complete destruction of the reactor core. Of the several contributing factors, perhaps the most important was that the operators did not have any good way to know exactly what was happening in the reactor and had to rely on making deductions from indirect evidence. As the Smithsonian Museum's web exhibit on the disaster puts it:

"Lacking any direct indicator of the water level in the reactor, the operators fail to grasp what is happening: the fuel rods are rupturing. Unbeknown to all, a molten mass of metal and fuel—some twenty tons in all—is spilling into the bottom of the reactor vessel. The bottom of the reactor vessel is steel, five inches thick. But even that thickness of steel would not be expected to hold up for more than a few hours against such heat. If this meltdown were known, drastic emergency measures, including evacuation of the region, would certainly be ordered. But the reactor vessel holds firm, and the molten uranium gradually begins to cool. The real danger passes, without anyone knowing how great it had been."

Safety is important in any plant, but nowhere is it more critical than in a nuclear power plant. For Cory Peters, Calibration Lab Supervisor and Chief Metrologist at Exelon PowerLabs—where he serves the needs of Exelon's ten nuclear power plants—that requires accurate sensors, precision measurement and Fluke meters.

The scope of Cory's job is not small. Exelon is one of the nation's largest electric utilities with more than $19 billion in annual revenues. It distributes electricity to over five million customers and operates the largest fleet of nuclear generating stations in the nation, producing 130 million net megawatt-hours of electricity per year; that's about 20 percent of total U.S. nuclear power capacity.

The reason that the sensors are so important is that operators can't actually see what is happening in the plant, especially not in the harsh area. The accident twenty-five years ago at the Three Mile Island Unit 2 plant—which Exelon does not own and did not operate at the time—showed just how critical those sensors are.

It would be six years after the accident until the extent of the meltdown, and the danger, was really understood. But the industry, and the Nuclear Regulatory Commission (NRC), did not wait. Within months after the accident, they set about revising and strengthening regulations, procedures and best practices. Many of those changes still affect practices today.

At that time, many nuclear power plants had Barksdale pressure switches and Yarway level switches installed to monitor reactor water level and pressure. These devices had begun to show their age and could no longer meet tight specifications. They could not simply be replaced, though, because they were not qualified to meet the post-accident operating conditions that the NRC had defined after the Three Mile Island accident.

Plants were then faced with installing analog trip systems consisting of a transmitter, current-to-voltage converters and trip modules to take the place of a once simple switch. Transmitters such as the Rosemount model 1153 became an industry standard for monitoring reactor water level and pressure. The industry chose Rosemount because it was the most reliable transmitter that was nuclear qualified for temperature and radiation. A typical 'smart' transmitter might only last a year in a harsh radiation area before the cumulative gamma dose would destroy the transmitter's internal IC's. The Rosemount 1153, on the other hand, is all analog, discrete hardened components and could last 30 years in the same radiation environment.

At Exelon, engineers then began considering how to test and calibrate the Rosemounts. In some of the plants, two wires were already installed for the simple pressure switches located on various remote racks. Cory Peters relayed, "The plan was to replace each switch with a transmitter and use the existing two wires to pass a 4 mA to 20 mA current to an analog nest outside the harsh area. In order to calibrate the transmitters, the current loop would have to be monitored locally while an appropriate pressure was applied to the transmitter."

One approach would be to install test jacks to monitor the current with a removable plug to break the current. Another approach would be to lift the leads, but lifted leads can lead to errors and inadvertent scrams. "It was decided to use the Rosemount's internal test diode to monitor current without having to lift leads or other terminals. That called for a current meter with low resistance, to forward bias the test diode so all the transmitter loop current would pass through the test meter."

"The logical step," said Peters, "was to look to our Fluke meters. They were already part of our standard instrumentation set. For example, we use the Fluke 189 handheld multimeter to monitor voltage levels off the secondary of our high-voltage dividers; the meter's high impedance makes it ideal for isolation from ground. For another example, our quality inspectors do min-max recording with the Fluke 45 bench DMM, so they can characterize the exact point of actuation on relays."

PowerLabs found that the Fluke 45, with less than 10 ohms of resistance for current measurements, fit the bill. As a result, the plant personnel can certify the performance of the sensors. (Peters and his team at PowerLabs are now evaluating the replacement for the Fluke 45, the Fluke 8808, and the Fluke 289 to replace the 189 handheld.) In the meantime, Exelon's operators know what is happening in their reactors, and Exelon can continue to maintain its excellent safety record. And that, of course, is good news for all of us.

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