Circuit Breaker Ranking Tool Saves Con Edison Millions

Historically, maintenance of high-voltage circuit breakers has been based on service time and, to a lesser extent, on operations count—the number of times the breaker has been operated. This simple approach has served the industry well for many years. But concerns about aging infrastructure, limited maintenance resources, and rising expectations for reliability are prompting maintenance and asset managers to investigate other, more sophisticated approaches to circuit breaker maintenance.

EPRI assessments have shown that for most breaker components, wear is not time-dependent, and the number of operations is not the only factor driving deterioration. Circuit breaker failure largely depends on breaker design, location, and application. Some breakers see more severe service duty than others because of their position in the power system.

In response to this new understanding, EPRI has developed a data-driven maintenance decision methodology that better reflects each breaker's actual condition and operating environment. The new tool allows a company to rank the condition of its entire breaker fleet and direct resources to the units most in need of attention. The methodology has been applied at several utilities with success.

Making Use of Existing Data

"Companies produce a lot of data on breaker condition in the course of normal operation and maintenance, but this valuable information is often underused because it's not in a form that can be easily applied in decision making," said project manager Bhavin Desai. "We have been developing algorithms for a number of years to convert the data into useful information that can drive meaningful actions without the expense of further data gathering."

The EPRI tool allows the user to gather information on the circuit breaker fleet from various sources and have it at his or her fingertips. It can rank a breaker's condition relative to the rest of the fleet and gauge the applicability of specific maintenance activities, including diagnostic testing. For a broader perspective, it enables the user to see trends within the breaker fleet, identify potential problem areas, and document the mitigation of failure risk in considerable detail. Because the tool is spreadsheet-based, the user can sort and group the breakers by type, voltage class, specific model, position on the system, and so on.

Early Success

More than a dozen EPRI members have been involved in developing the ranking tool, and several have applied prototype versions on their systems. Last year Consolidated Edison used the program to identify the circuit breakers least likely to need attention. By extending the intervals between major maintenance inspections for these units, the company saved about $3 million for 2009 and expects equivalent savings in the coming years without any reduction in performance.

"One of the biggest challenges for T&D maintenance is dealing with the sheer volume of equipment," said Matt Walther, asset manager for Con Edison's substation operations. "Using the data from the maintenance tool helps us whittle that number down and make better choices on which breakers we perform maintenance on. It really enables our team to focus limited resources on the right equipment, thus improving productivity while retaining a high level of reliability."

James Haufler, a Con Edison senior substations engineer, pointed out that enhanced access to maintenance data can provide ancillary benefits: "In addition to giving us good guidance on breaker risk, the maintenance tool has helped us better identify SF_6 gas leaks, saving money and improving our environmental stewardship. All these benefits have been accomplished with relatively low expenditures."

Such early successes in applying the maintenance decision tool—and the substantial savings—have strongly validated the data-driven condition-monitoring approach. EPRI continues to refine the ranking algorithms with assistance and feedback from its funding members.

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Nondestructive Hydrogen Monitoring for Nuclear Fuel Applications

The channel boxes, commonly referred to simply as "channels," that surround fuel bundle assemblies in today's boiling water reactors (BWRs) are made of zirconium alloys—primarily Zircaloy-2 and Zircaloy-4. Resistant to the high radiation and temperatures of nuclear reactors, these channel materials nonetheless are vulnerable to hydrogen, which is absorbed during corrosion of the Zircaloy alloy. Hydrogen absorption can degrade the mechanical properties of Zircaloy, leading to embrittlement, elongation, and distortion of the channel boxes. Distortion of these channels can interfere with the free movement of the fuel bundles' control blades, causing operational issues, and may pose safety concerns.

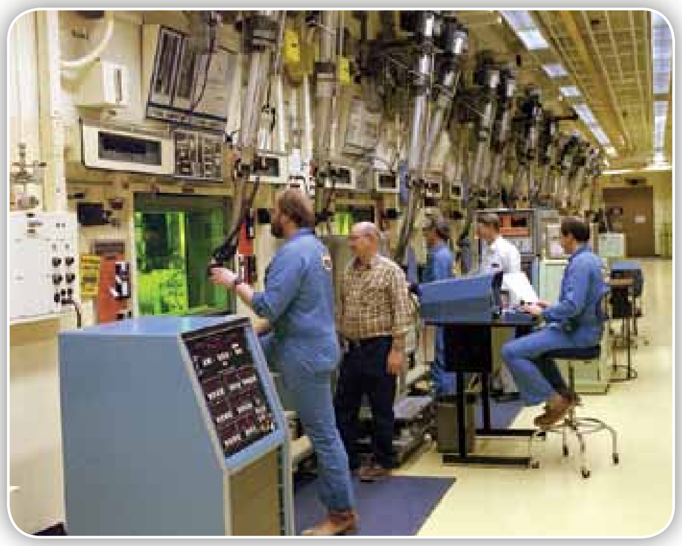
Destructive testing is the only method currently available to accurately detect the amount of hydrogen in a Zircaloy channel. In this procedure, a sample of the channel material is removed for testing—thereby destroying the channel—and shipped to a test laboratory in a shielded cask. Since the original channel is destroyed, a replacement channel must be installed for fuel bundles to be reinserted into the core. All told, this sequence of steps costs considerable time and money.

Because metals in the core become irradiated during service, the assessment must be performed in one of a relative handful of laboratories equipped with a "hot cell" for testing radioactive materials. Each test costs about $300,000–$400,000, providing strong incentive to reduce the costs of hydrogen level assessment in these channels and other nuclear fuel components.

Looking for a Nondestructive Alternative

For decades, EPRI and others have sought a nondestructive, *in situ* method of assessing hydrogen levels in channels and other zirconium alloy nuclear fuel components. Some proprietary methods have been researched but have not been widely demonstrated or made available to the entire industry. Many researchers have tried to quantify hydrogen levels by measuring impedance changes using high-frequency (MHz-level) eddy currents. This method has proved highly sensitive to the temperature of the channels and surrounding water and to irradiation effects, undermining the reliability of the results.

An April 2009 EPRI report (1018541) documented preliminary results showing that electronic property analyses using thermoelectric power and low-frequency impedance measurements can successfully measure hydrogen content in Zircaloy-4. In light of this development, EPRI is examining the use of swept-frequency methods to cover a wider range of eddy-current frequencies—from kHz to MHz—to quantify hydrogen levels without an adverse temperature effect on results.



Testing of Zircaloy channels for hydrogen absorption must currently be carried out in a heavily shielded hot cell facility at great expense.

The goal of this current laboratory research is to develop an *in situ* hydrogen monitor for zirconium alloys commonly used in fuel rods and channels. Zircaloy-4—one of the two predominant zirconium alloys in use—typically is used as fuel cladding in pressurized water reactors and Canadian deuterium/uranium reactors. Zircaloy-2 (a common BWR channel and fuel rod cladding material) and other advanced zirconium alloys also are being tested.

The Research Plan

EPRI research continues on a range of fuel issues related to hydrogen effects:

- Investigate the effects of hydride formation in different zirconium alloys;
- Develop standards and nondestructive characterization techniques based on proven sensor technologies;
- Develop a nondestructive hydrogen evaluation system for eventual demonstrations in hot cells and spent fuel pools; and
- Prepare an in-service inspection procedure and manual for the developed nondestructive evaluation system.

EPRI expects pilot demonstrations at various component-inspection vendors' facilities by the end of 2010. Utility pilot demonstrations will follow if the technology proves feasible.

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