During an extended shutdown in 2003, MPR’s client FirstEnergy Nuclear Operating Company (FENOC) determined that the High Pressure Injection (HPI) pumps at the Davis-Besse Nuclear Power Station in Ohio may not function properly. Following a hypothesized loss of coolant accident (LOCA), the water to be pumped will contain debris created by the accident (paint chips, insulation, dirt, etc.). Although there is a strainer at the upstream containment sump, debris smaller than 3/16 of an inch can reach the pumps and potentially degrade them.

FENOC wanted to restart the plant as soon as possible. Because resolving the HPI pump issue was required prior to restart, FENOC tapped MPR to help. MPR’s solution provided a faster schedule, lower cost, and simpler approach than wholesale replacement of the pumps.

**MPR’s Approach**

The primary concern with post-LOCA pump operation is the potential for the pumped debris to plug and degrade the hydrostatic bearing. Another concern is the potential for debris to erode internal clearances, degrading pump performance.

To address the hydrostatic bearing plugging concern, MPR designed a special purpose, simple strainer for the pump internal passages to remove the debris. The MPR design is self-cleaning, thereby ensuring that the strainer will not become plugged. MPR also developed and validated a new debris-tolerant hydrostatic bearing, expediting the design by using the results of previous work by the original pump designer (Pump Guinard). MPR addressed the potential for erosion of the pump internal clearances by designing and installing new pump components with wear resistant, hardened surfaces.

MPR’s work provided a total solution to the HPI pump issue:

- Project management
- Design of the pump modifications
- Analyses to demonstrate the pumps will operate satisfactorily
- Test program to validate the modified design and to quantify the impact of debris
- Modifications to the pumps

• Procedures for in-plant testing to validate the pump analytical models
• Engineering documents and change requests to support implementation
• Technical leadership for FENOC’s interactions with the Nuclear Regulatory Commission (NRC)

To provide the optimum solution, MPR applied the best resources to this project. We engaged two main subcontractors – Wyle Laboratories for the qualification testing and Flowserve for the pump modifications. The test program included full-scale pump components under debris

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Preventing Blackouts by Identifying Relay Hidden Failures

by David Elizondo

The August 14, 2003 blackout in the Northeastern part of the United States and Canada was the result of a combination of failures. Protection systems are in place to isolate elements of the grid in the event of failures and prevent serious disruptions (termed wide area disturbances). Prior to the 2003 blackout, predictions of the event unfolding as it did would have been dismissed as incredible.

Transmission system operators perform contingency analyses to confirm that the system is sufficiently robust at any point in time to tolerate failures. A contingency is defined as the loss of a power system major element, for example, a transmission line or a generator. A double (N-2) contingency is then the loss of two major elements, either sequentially or simultaneously. Until recently, criteria for system reliability have been based on single contingency. Increasingly, system operators now consider double contingency as the appropriate level for reliability. A study of disturbance reports from 1988 to 1996 concluded that double contingencies contributed significantly to wide area disturbances. A majority of these are caused by relay mis-operations due to hidden failures.

Hidden failures in protection systems are defects that will cause a relay to incorrectly remove a power system element after an event that should not warrant this action. An example is the failure of a time delay relay only seen if the related sensing relay is triggered. Unfortunately, relay mis-operations caused by hidden failures tend to occur when the power system is already under stress, such as during faults, under-voltages, overloads, or other switching events. This relay hidden failure significantly increases the probability of a wide area disturbance.

MPR’s Approach to Addressing Hidden Failures

Detecting hidden failures is a difficult task involving both increased manual surveillance and the use of failure detection circuitry in protective relays. Applying this remedy to all protective relay circuits on a power system would be excessively expensive. However, MPR has developed techniques to reduce the complexity and cost of detecting and correcting hidden failures by analyzing systems to identify those failure scenarios that have serious system-wide consequences.

MPR’s approach applies system knowledge, relay operation insights and system simulation to focus on potential hidden failures in the context of a double contingency. The technique determines an index of severity to prioritize the areas of the power system for protection against hidden failures. The index of severity categorizes protection schemes according to the overall consequences of failure.

Relay operation requires considerable attention by utility operators, and data on relay performance during past disturbance events are typically available. These data are a primary input to our method of hidden failure analysis. These data and other developed techniques are combined with simulation results to identify double contingencies and to examine the protection schemes that are critical to avoiding wide area disturbances. MPR engineers then use this information to develop a corrective design, revised operating procedures and/or identify maintenance related items for only those relays that are identified as susceptible to hidden faults.

A sample power system is shown below. In this case, a double contingency

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Since April 2001, MPR has been working with Washington, D.C.-based Bioscan, Inc. on the development of products to automate the fabrication of carbon-11 (¹¹C) tracer compounds for use in positron emission tomography (PET) imaging. These products are for use in nuclear medicine and life science research, and by commercial producers in the rapidly growing field of nuclear imaging.

A PET scan non-invasively produces three-dimensional images of the heart, brain or other organs at work. These scans are used in the diagnosis and management of cancer, brain disorders and heart disease. PET has a unique ability to image complex biological attributes such as blood flow, metabolism, and concentrations of various compounds. Use of PET is more effective at detecting early stage cancers and at determining effectiveness of therapy because changes in cell function are more telling than physical changes alone.

PET imaging is accomplished by injecting glucose that has been labeled or tagged with a small amount of radioactive material. These radioactive tracers circulate through the body and emit gamma rays that are detected by the PET scanner. A computer uses the measurements to create images based on the function of the cells of the body. For example, cancer cells typically use more glucose than normal body cells and, therefore, collect more tracer, which is revealed on a PET scan.

Until recently, tracer compounds have been produced using homemade systems developed and pieced together on-site by scientists at research hospitals. These systems are able to be run only by the creator, are difficult and expensive to maintain, and cannot produce repeatable, high-quality yields. Rejection of bad batches leads to a high cost of production and considerable waste. Bioscan saw the need in this market for a fully automated chemical production system. Using patented technology developed by Professor Alan Wilson in Toronto, Bioscan contracted MPR to develop a practical, safe and user-friendly product.

MPR rapidly developed the first system in time to show a prototype at a key international industry trade show: The Society of Nuclear Medicine. This system is called the Auto-Loop, named after the stainless steel coiled loop where the chemicals are reacted. Within two months MPR produced a fully functional initial prototype with companion software. The design of the system was challenging because of the small (microliter) volumes of fluids being handled and other factors that had not been addressed well in the homemade systems. Specifically, chemical contamination

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loading corresponding to post-LOCA operation. All activities were performed in accordance with the requirements of the MPR and subcontractor QA Programs, which satisfied 10CFR50 Appendix B.

Results

The project was completed successfully without delaying plant restart. The NRC performed detailed reviews of the project and determined that all criteria had been met and that appropriate approaches were used in all analysis, design, testing, and modification.

This project is an example of the benefits MPR provides in the area of component engineering. MPR has knowledge and experience with pumps that are comparable to, and in many cases greater than, the remaining nuclear pump vendors. MPR combined this pump expertise with our overall experience with nuclear plant design, operation, and licensing to provide FENOC with a total solution to the HPI pump concerns.

Future Applications

As described in NRC Bulletin 2003-01, the detrimental impact of debris on Emergency Core Cooling System equipment is one of the issues that nuclear plant owners must address to resolve NRC Generic Safety Issue 191 and an upcoming NRC generic letter on the same subject. Plant owners must also ensure that the debris that stays on the containment sump strainer does not “starve” the pumps. Based on this HPI pump project experience, MPR can support many other plant owners over the next several years as they address similar issues.

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(loss of lines 91 and 92) causes a severe impact because it leads to the operation of protective relays that open other circuits (circuit breakers shown as red boxes).

In this case, the disconnection of lines 91 and 92 is given a high index of severity and the lines and associated relays would be scheduled for additional surveillance until corrective actions are developed and implemented to protect against hidden failures.

Recent NERC Initiatives and Related MPR Services

The hidden failure identification approach described above is a cost effective method of addressing national electrical issues, such as those raised by the North American Electric Reliability Council (NERC). The NERC is a voluntary association of member utilities responsible for establishing guidelines, best practices and standards for assuring the reliable operation of the electric power grid. This body recently issued recommendations in response to the 2003 blackout. For more information, see the NERC web site at www.nerc.com. Application of the MPR approach for hidden failure analysis is a proven and prudent means for addressing the NERC objective of system protection related to distance relay (Z3) operation.

The NERC recommendations are broad, covering such areas as system protection; system design, planning, and operation criteria; reactive power control and voltage control practices; and system modeling. MPR is able to assist our clients in addressing NERC recommendations in all of these areas.

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needs to be avoided, the user cannot make or break fluid fittings during the process, and the system must be automatically cleaned and dried after each synthesis cycle. MPR’s device met all of these requirements and formed the basis for a joint international patent application with Bioscan.

MPR received positive feedback from industry experts at the show, which was helpful to the completion of the prototype. Extensive testing of MPR’s device showed that the system is remarkably efficient, easy-to-use, and achieves consistently high yields.

A key part of the Auto-Loop system is the software that implements an intuitive and interactive graphical interface for performing the syntheses. The software was developed to comply with current Good Manufacturing Practices (cGMP) and to be used by lab technicians with limited knowledge of the synthesis process. The software in conjunction with the simple, robust equipment allow consistent and reliable synthesis runs to be performed with minimal oversight by the user.

Broad Scale Acceptance

The Auto-Loop system is currently installed and being successfully used at laboratories worldwide. Building on this success, MPR is now developing additional related products for Bioscan. For more information on Bioscan, see www.bioscan.com.
Making U.S. Navy Ships More Survivable

by Patrick Hardin and Eric Runnerstrom

A major objective of new U.S. Navy ship development is to reduce shipboard manning. A key function that affects manning is the ability to recover from a weapon hit. In 1987, the USS STARK was hit by two missiles, and fire spread rapidly from the initial damage area. Firemain damage impeded effective firefighting. Firefighting and damage control heavily taxed the ship’s crew for over 30 hours. Although damage control and survivability have always been key factors in Navy ship design, the STARK incident spurred further developments and improvements in ship survivability.

In the early 1990s, working with the U.S. Navy, MPR analyzed results of post-missile fire tests and established quantitative, time-based objectives for setting boundaries to prevent fire spread. These objectives provide a benchmark for fire protection performance in ship development today. MPR assisted the Navy with several other efforts to develop, test and implement improvements in firefighting. MPR defined test objectives and evaluated results of firefighting doctrine tests aboard the Naval Research Laboratory test ship, ex-USS SHADWELL. MPR defined lessons learned from the tests, and updated firefighting doctrine accordingly.

MPR was also instrumental in the implementation of Self Contained Breathing Apparatus (SCBA) throughout the Fleet, to replace outdated equipment.

Following successful tests of a machinery-space water mist system (to replace Halon) and a damage control deck smoke ejection system, MPR prepared doctrine for use of these new capabilities.

In the late 1990s, the Navy’s program on Damage Control Automation for Reduced Manning (DC-ARM) developed a cornerstone for damage recovery and improved firefighting aboard new Navy ships. MPR developed “human-engineered” displays and decision aids vital to improving the damage control response. MPR’s distributed, hierarchical control system operated the firemain. This system included MPR’s patented “hydraulic resistance” logic using autonomous “smart valves.” The DC-ARM program demonstrated that typical damage control manning can be reduced substantially using a combination of improvements in doctrine and organization coupled with technology like MPR’s human-engineered displays and smart valves. At the same time, these changes improve damage control performance.

In 2002, the Navy developed a new “primary damage area” cooling system to deliver water into the blast damage area after a weapon hit, using nozzles that penetrate division bulkheads. (Prior systems would not necessarily survive and function in a blast area.) The Automated Fire Suppression System (AFSS) for the advanced DD(X) destroyer integrates the survivable cooling system architecture with DC-ARM technology. MPR helped the shipbuilder/Navy team define the AFSS concept, and has been supporting the subsequent engineering effort. A major milestone for this technology was met with a recent full scale, at-sea live weapon test. The smart valves successfully isolated the damaged piping using MPR’s hydraulic resistance logic, and the primary damage area cooling system successfully prevented spread of the fire.

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The cooling system extinguished most of the fire in the primary damage area, exceeding the performance requirements.

MPR recently won a contract to provide smart valve technology to shipbuilders for the chilled water systems in new destroyers. The smart valves will automatically isolate damaged piping and switch vital loads from the damaged to the surviving chilled water main. MPR is providing smart valve and device network hardware and software fully qualified to Navy standards for vital equipment. This system will be the first use of this technology aboard an operating U.S. Navy ship.

MPR is proud to be part of the Navy-shipbuilder team that is developing and applying new technology to improve the survivability of Navy ships.