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DIGITAL INSTRUMENTATION IN A NUCLEAR POWER PLANT

NUCLEAR POWER PLANTS ARE STAYING IN SERVICE FOR INCREASINGLY LONGER PERIODS OF TIME, WITH MANY EXPECTED TO CONTINUE OPERATIONS FOR DECADES TO COME. PERHAPS IT'S TIME FOR THESE AGING PLANTS TO DO MORE THAN JUST "REPLACE IN KIND."

BY BILL FITZGERALD AND CHARLES LINDEN

Many interesting developments are occurring in the nuclear industry today, including falling costs and increasing plant reliability. Capacity is now at more than 90 percent. As a result, nuclear plants are making money and looking pretty good compared to the other fossil energy options such as combined cycle and coal. Most of the plants have already filed for license extensions that will have them running for an average of 30 years more.

While this is generally viewed as very good news, some challenging issues have popped up as a result of the extensions to the plants' operating lives. Since the plants were built, they have been operated for the most part with a "replace in kind" mentality. In other words, as long as plants could maintain the existing infrastructure by making replacements using identical equipment, they took that approach in maintaining the design basis of components in plant systems.

Back to the '70s

From an instrumentation standpoint, most plants today look very much like they did in the 1970s. Unlike process plants outside of the nuclear industry, they operate with no centralized control system. Instead, they use the local pneumatic control and analog process field devices (transmitters and control valves). Because of overriding concerns with reliability and safety, this approach has been the general rule for the nuclear industry over several decades. Changes in instrumentation infrastructure have to hold up against original safety system designs for the plant and be processed through an engineering evaluation to verify that no impact on safety will occur. (Protecting the general safety of the public is part of the plant's mission.) In most cases, these evaluations are so expensive that no changes are made unless absolutely necessary.

This approach to infrastructure change generally has not been considered a problem as long as the plants were working to their original schedules, which called for the average plant to shut down in the next 8 to 10 years. The plan was to continue that approach and find the replacement equipment any way they could until the plant was decommissioned. However, problems were already creeping up with instrumentation, because equipment was becoming obsolete and qualified safety-related spare parts were very hard to procure.

Replace in Kind?

In addition to these increasing support costs, a growing concern has developed that continuing down this track of "replace in kind" could have a negative impact on overall reliability. Not only was instrumentation getting older and less reliable, the variability in the process itself was higher than it would be with a more modern approach. This variability can lead to premature failure of equipment subjected to cycles in service conditions that would not occur in a plant operating more smoothly.

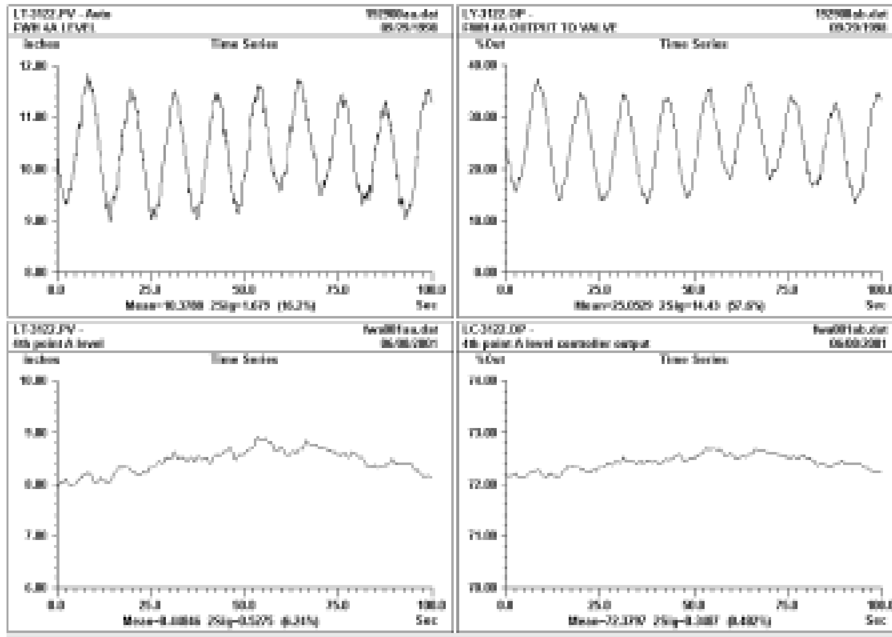

Figure 1. Feedwater heater cycling, before and after improvements

An example is shown in Figure 1. The top two curves show a typical feedwater heater operating in a nuclear power plant. The system was being run with local pneumatic controllers coupled to obsolete, oversized control valves with slow, unresponsive positioners. The result was that the level in this feedwater heater was swinging by more than 3 inches or 30% of the optimum set point for thermal efficiency. This cycling was wearing out the controllers, valves, positioners, and heaters, costing the plant a lot. The lower curves show an optimized solution based on modern digital instru-

Figure 2. Original installation with spool valve positioner

Figure 3. Original installation, I/P transducer and actuator

mentation and properly sized control valves; note the large improvement. If all the critical loops in a typical power plant could be stabilized as shown here, cycling-related problems would be greatly reduced and overall reliability would increase. If the loop is more stable, the plant could be run closer to operating limits, providing additional gains associated with higher capacity and efficiency.

Another factor that enters into the mix is that large numbers of staff in many plants may retire in the next five years and that means the personnel who know how to maintain the existing infrastructure could be gone. Attracting and retaining the next generation of process control engineers and technicians to a plant still being operated on local pneumatic controls may be no easy matter.

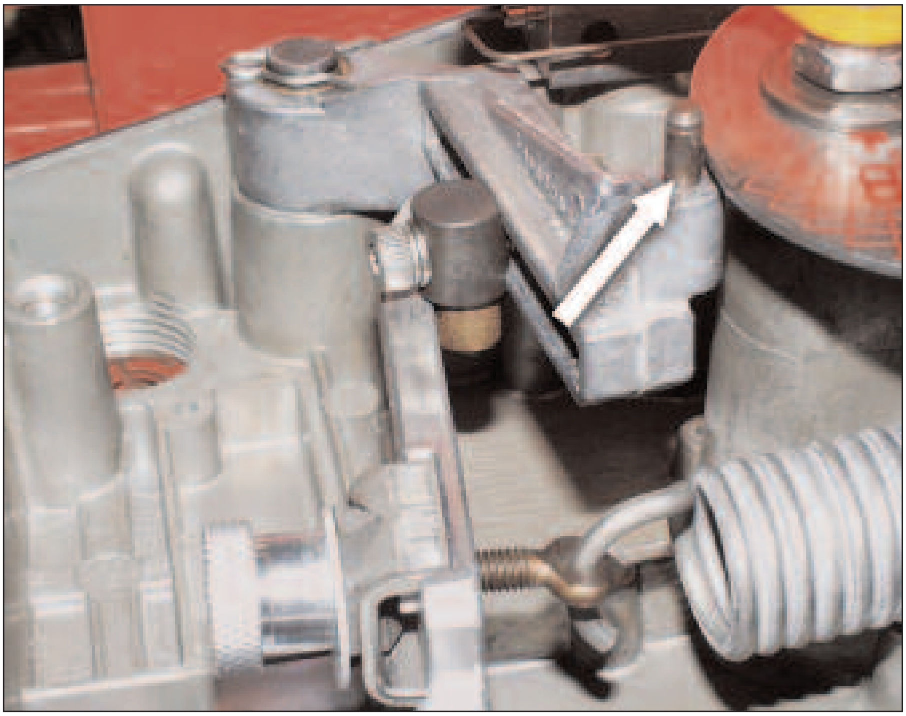

Figure 4. Closeup of feedback linkage inside positioner showing bearing roller failure

A Digital Transformation

With these issues in mind, several progressive nuclear plants are now looking at how to manage the transition into today's state-of-the-art digital instrumentation. The first step may be implementing a centralized control system to provide better visibility to the process for operators. These modern systems also provide access to control-enhancing techniques such as adaptive tuning, which facilitate a much more aggressive approach to process control. That control can greatly reduce the process cycling described above and deliver a more productive and reliable plant.

However, if instrumentation modernization stopped with installation of a centralized control system, the end-user would miss out on many significant opportunities to improve performance of the field devices themselves. The field devices, like the control systems, have also gone through a digital transformation resulting in more accuracy, stability, and responsiveness. The new devices can be set up and commissioned in a fraction of the time it would have taken to set up their analog predecessors.

Perhaps most importantly, these digital devices can communicate by sending real-time information back to the centralized control system, providing vital information on the state of the process and the devices themselves. This two-way communication can effectively deliver a condition-based, on-line, in-service predictive maintenance program that can greatly enhance process yield (more megawatts), while reducing the cost of maintaining the infrastructure over time. The bottom line is: *there will be more bottom line*.

Fort Calhoun Goes Digital

Taking these issues into consideration, a team of engineers at Fort Calhoun

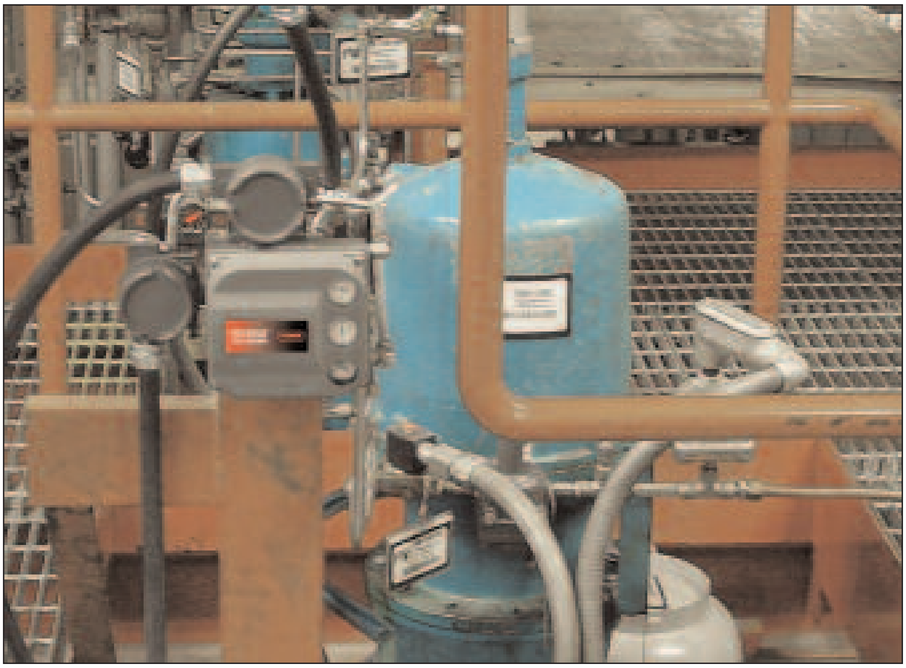

Figure 5. New installation with remote-mounted digital positioner

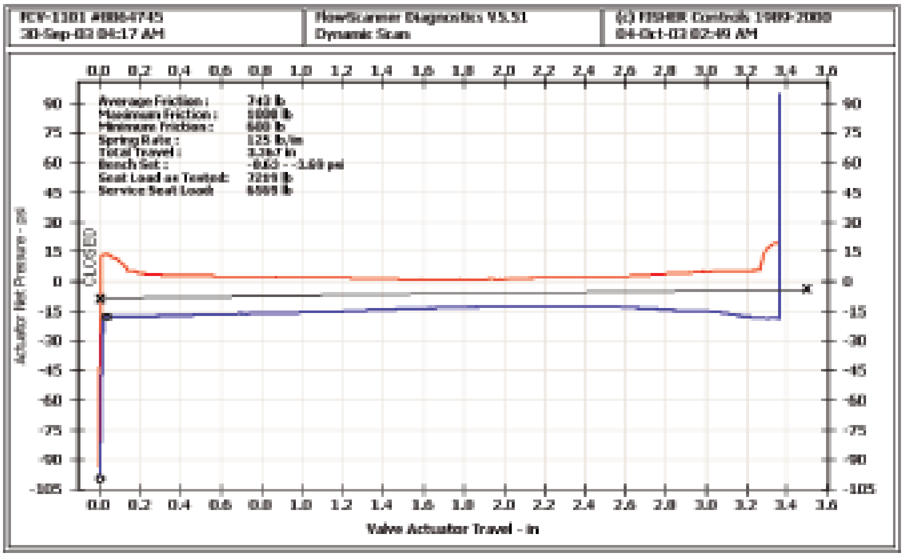

Figure 6. Diagnostic trace showing proper operation of valve assembly

Nuclear Station (a 500 MW PWR) near Omaha, NE, decided to transition to digital instrumentation in the field. The management team at the utility had determined this was the road to a more productive future—a future that would guarantee the long-term viability of the plant to 2033. As a result, they had already decided to install a modern centralized control system. But the strategy with respect to upgrading digital devices had yet to be fully defined.

The first task they needed to accomplish was to pick an area of the plant where they could concentrate efforts. In reviewing plant performance, the feedwater regulating valves appeared to be a good target. The plant had experienced two failures on the positioners on these valves over a 30-month period beginning in 2001. Both failures could have tripped the plant, which is very expensive in terms of actual costs, regulatory concerns, and lost revenue. Most plants assign $1 million-plus per day as the bottom-line economic impact of a forced outage. The existing positioners in question were old, analog spool-valve models that had serious problems with reliability because of design problems made worse by cycling in the valves and high ambient vibration.

Figures 2 and 3 show the original installation, while Figure 4 shows the inside of the positioner where a failure occurred. The cam follower bearing that was part of the feedback mechanism had failed, and the valve had changed position. This reduced the level in one of two steam generators, causing a plant transient. Because the dynamic performance of the positioner and valve combination were not very good, excessive cycling of the valves made the situation even worse.

Given the financial impact failures had on the plant, it was relatively easy to get the go-ahead for a design modification to feature digital positioners on these valves, which were considered critical components in the plant. After review of general industry and plant operating information, several positioners of the existing type were identified as having out-of-calibration problems, internal shuttle valve failures (i.e. spool valve), and loose/binding linkage. The failures were related mostly to vibration of system piping or lack of maintenance. Since linkage problems were so common, plant management decided to select a positioner with minimal or less linkage.

Because most nuclear power plants want refueling outage maintenance to average off-line status of 35 days or less, the time required to quickly set up and easily calibrate a positioner becomes critical. Modern digital positioners can be calibrated is less than 10 minutes, while older pneumatic positioners may take up to four hours.

Many plants are presently supplementing their maintenance staff with outside vendors or personnel loaned from other nuclear plants. This means technicians may not always have the best level of experience since so many experienced technicians are retiring from the work force. Selecting a positioner with a minimal number of internal electrical and mechanical parts is very important for maintenance and reliability. Another factor in selecting

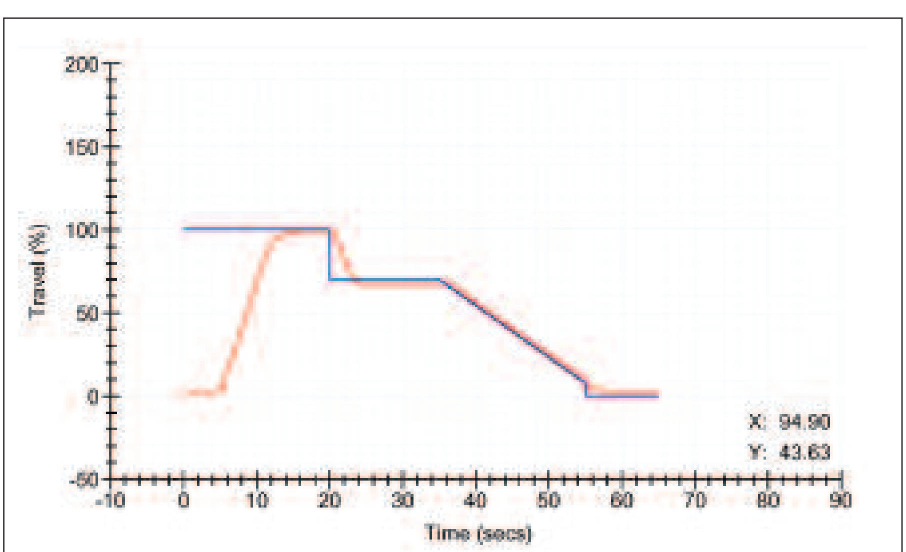

Figure 7. Simulated ramp test, showing valve's ability to track input signal

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a positioner is the capability to configure it with either a diaphragm or piston actuator. Also, fewer parts mean less inventory, less cost, and less parts to troubleshoot.

The Selection Process

With all these qualifiers in mind, the plant went through an extensive selection process that focused on the following characteristics:

- Reliability
- Dynamic performance
- Diagnostics
- Ease of set-up and calibration
- Ease of installation and maintenance
- Vendor support for training and utilization
- Digital "history"—development, troubleshooting, de-bugging, etc.
- Long-term compatibility with other systems' upgrades
- Remote mounting capability

Still, successful implementation depended on more than just selecting the right instrument. Since digital instrumentation was new to the plant, the team took extra care to insure that any plant staff that could be affected by changes were part of the planning process, including maintenance, engineering, I&C, and operations personnel.

Figure 5 shows the new positioner in place, remotely mounted on a pipe stand, isolating it from valve vibration. Overall, it's a much simpler installation. Figure 6) shows a diagnostic trace on the valve and actuator assembly showing smooth operation, and Figure 7 shows the simulated ramp test verifying that the valve assembly response (the red line) accurately tracks the input curve (the blue line) for the simulated ramp.

New Approach Yields Advantages

Significant advantages associated with the new approach include:

- Calibration, setup, and diagnostic signature time for the system was cut from 24 man-hours to four man-hours, a huge advantage for a nuclear power plant where field time can be very costly.
- Component reliability was increased.
- Quality of process control improved, reducing variability from 5% down to 1%. In other words, the steam generator level was much more stable.
- System reliability improved; the valves work less to control the steam generator level.
- Response to load changes (transients) and set-point changes improved.
- Vendor support is better.
- Spare parts with a current product are cheaper.
- Remote mount model cut down on background vibration levels.
- The need for portable (luggable) diagnostic equipment to check out the valve was eliminated. Instead, everything can be done on-line, in service via the two-way digital communication link described earlier. The plant gets continuous readings on valve and system performance that leads to just-in-time corrective action—a true predictive approach to maintenance.

To date, the plant is very happy with modifications to the feedwater heater valves and is looking for more opportunities to harness the power of the digital instrumentation structure. In the long term, plant management plans to proceed with installing a centralized control system that, when tied into digital communicating field devices, will give them another boost in their operational performance to keep the plant competitive and save customers money.

Based on the experience at Fort Calhoun, several nuclear power plants have implemented plans to upgrade to digital positioners to improve plant reliability. In addition, many are looking at upgrading digital process control systems that have the capability to monitor, trend, calibrate, and perform on-line diagnostics to assess process control system health. As a result of these positive developments, plant operators will have a better understanding of how to optimize the performance of the plant, and nuclear power will continue to be a viable alternative as the nation plots its energy future. **VM**

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