Process control upgrades yield huge operational improvements

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Many nuclear plants in North America, built in the late 60's and 70's, have not taken advantage of subsequent process control improvements. The situation is changing as utilities try to extend operating licenses and improve returns on investment. A particular area of attention is the feedwater heaters, normally based on local pneumatic controls that are relatively slow and inaccurate. Hence heater levels swing back and forth across the optimum, resulting in very poor heat transfer and high maintenance on heater tubes. Heater drain valves cycle and leak compounding maintenance and efficiency problems. This unstable operation also results in major service excursions that shorten effective maintenance life, making heaters one of the highest maintenance areas in the plant.

A case study is presented of a process control audit of a heater systems, which has resulted in the proposed implementation of a digital distributed process control system for the heaters along with a complete upgrade of the level controls and field devices. This planned upgrade is expected to stabilize heater levels, resulting in significant efficiency gains and lower maintenance bills. Overall the payback period for this investment should be less than six months and the plant is looking now for more opportunities that can provide even bigger gains.

Most of the world's nuclear power capacity was brought into operation in the 70's and 80's. Given the inherent safety concerns surrounding this type of power production, it has been very conservative in terms of technology platforms initially utilized as well as any potential upgrades. The end result of these two defining characteristics is that a typical nuclear power plant is operating with outdated technology. This is particularly true with respect to process control technology, where the power industry in general has made great strides in improving benchmarked process control performance over the last 40 years. Unfortunately, very few of these improvements have made their way into operating nuclear plants.

The other characteristics that play into this discussion are the general move towards deregulation worldwide and the regional shortages seen in selected areas. Nuclear capacity is suddenly becoming a very important element in the world power picture, and power producers now must decide how they can squeeze every megawatt out of their nuclear plants while keeping them on line just as long as possible. As a result, we are now seeing a number of plants in North America looking at extending plant operating licenses.

Given this background, the balance of this paper supports the following points:

- That there are many process control improvements that can be made in most nuclear power plants to take advantage of the last 40 years technology evolution.
- That implementation of said technology will improve the financial return for these plants by improving efficiency, capacity, availability, and safety, while reducing maintenance and personnel costs.
- That this new technology that provides online diagnostics will assist these plants in adopting state of the art maintenance practices that will further improve availability and reduce maintenance expenses and plant trips.
- That to remain competitive over the long run, the industry must cast off its previous conservative approach to equipment upgrades, and instead begin to leverage new technology.

The case supporting these arguments is built around recent (on-going) experiences at a progressive power plant located in the midwestern United States. They recognized many of the same challenges mentioned above and have initiated a program that looks at how new technology might improve their operational and financial results.

In reviewing their operation, they found

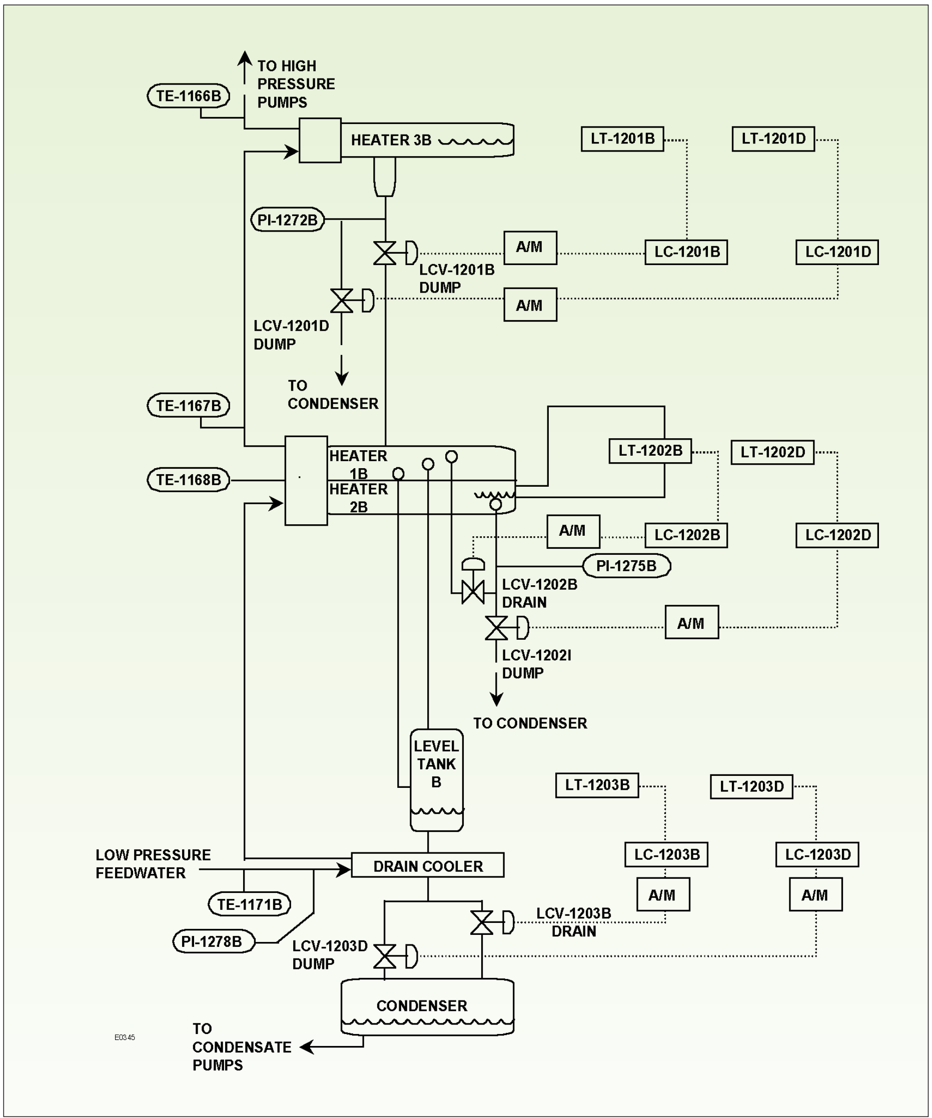

Fig. 1. Feedwater Heater Process Control Schematic

that their feedwater heaters might be a logical target. The only reason to utilize feedwater heaters is to improve steam cycle efficiency. So, if the heaters are not working properly, then efficiency and, hence, capacity is lost.

The plant discovered that the heaters are not operating smoothly, meaning that there is some real money being left on the table. This is further compounded by the fact that the heaters are a high maintenance item that demand a lot of attention from the plant staff.

The plant identified the heaters as the initial target for its process upgrade program, and contracted a process consulting firm to put together a plan to assess the current state of this system and look at corrective action.

Feedwater heater process control schematic

Before getting into the program itself, the process control system schematic (Figure 1) needs to be reviewed so that one can better understand the elements that were reviewed during the program.

There are two trains of heaters at this plant, A and B. This shows train B, which is very similar to train A. In both cases, there are three heaters linked together that ultimately dump into the condenser on the steam side. The system includes as primary elements the heaters themselves, feedwater flow loops, level transmitters, level controllers, and dump valve assemblies, including positioners.

Feedwater heaters are basically heat exchangers that take steam downstream of the “boiler” and utilize it to heat the feedwater before it enters the boiler. Feedwater comes in on one end, traverses the heater in tubes that are surrounded by steam that gives up heat to the feedwater and partially condenses. If everything works as it should, steam flow is controlled in relation to feedwater flow, and the water level in the heaters is maintained at a constant and optimum level to maximize heat transfer characteristics and minimize temperature and pressure swings on the mechanical components. As the reader will note in the findings below, many things can go wrong with this scheme that can result in some fairly significant bottom line problems at the plant level.

Process Audit Methodology

The generic process established to study and update process control infrastructure is called the Process Audit. It consists of the following key elements. Note that the process audit team is made up of external and internal personnel. The external team typically consists of process control experts, hardware consultants, and someone who can collect loop and device diagnostic data. Internally, the best results are seen when a senior member of the staff is assigned as a key contact. This individual ensures access to other key personnel on an as-needed basis.

The process steps are:

- The process control schematics are reviewed in detail so that the process team fully understands the desired function of the process control system in question.
- A discovery process that consists of background data collection, looking at maintenance records, talking to operators, reviewing actual hardware construction vs. service condition, equipment inspection, etc.
- The loops and control devices are then subjected to a series of tests that reveal how well the process variable is being controlled in relation to the setpoint. (By way of explanation, the process variable is the process value that is being controlled. In this case, it would be things like the water level in the heaters, and/or the flow through the control valves. The setpoint is the desired value at which we’d like to see the process variable controlled).
- Once diagnostics tests have been com-

Fig. 2. Control valve instrumented for test

pleted on the loop, the process control devices themselves are evaluated by running a series of controlled input tests and by noting how the devices respond to the programmed inputs. The photo left (Figure 2) shows a valve instrumented and set up for a diagnostic test that will tell how well it responds to the input signal.

Process audit results

The major findings of the audit are summarized below for each of the 3B heaters. Recognize that the actual audit report is much more detailed and voluminous. Only the major findings on three heaters could be covered here given the limitations on the length of this paper. Note that the results of the audit on the A side were very similar to those presented below.

Heater 3B

Observation of this heater showed actual level swings of ± 11% with a period of 5 seconds, far from ideal behavior. In looking for the root cause for this type of instability, one of the important tests run during the audit is a comparison of actual valve position to the command signal that comes out of the pneumatic controller. Ideally, the valve should track this very closely, or there will be errors introduced into the process loop that will make it difficult for the controller to actually maintain the desired setpoint. The higher the valve error, the bigger the swings in the process variable. In this case, the process variable is heater level, so valve error translates into higher than normal variations in the heater levels. As explained earlier, these level fluctuations swings reduce the efficiency of the heaters and increase the required maintenance.
The results of the first test are shown on the left (Figure 3).
The top curve shows the control signal sent to the valve from the controller. The bottom curve shows how the valve responded. We'll expand these two

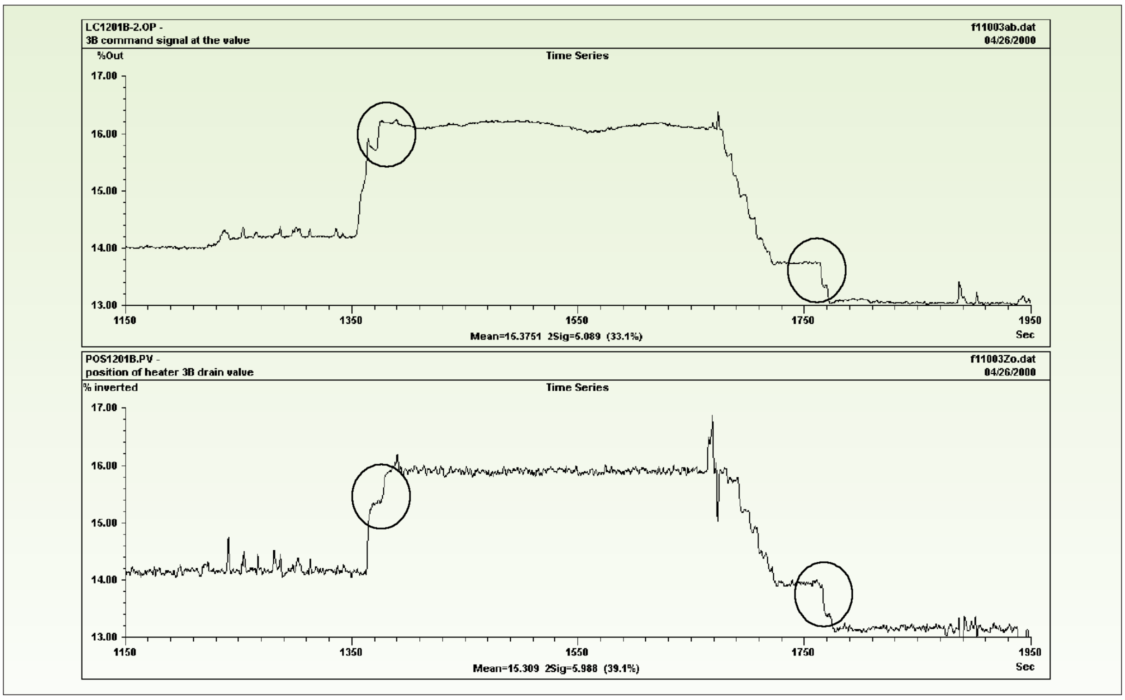

Fig. 3. Control performance for 3B

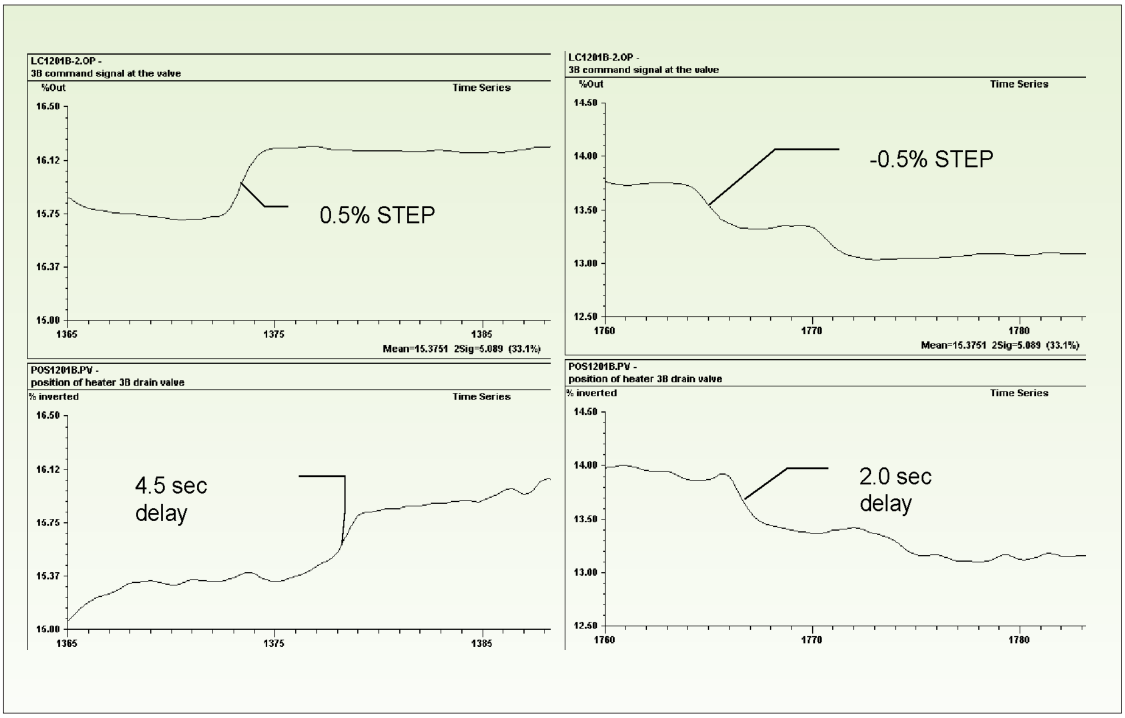

Fig. 4. Expanded view of performance curves shown in Fig.3.

NB: For higher resolution images of all Figures, please see the digital version of this text on our website, at www.valve-world.net

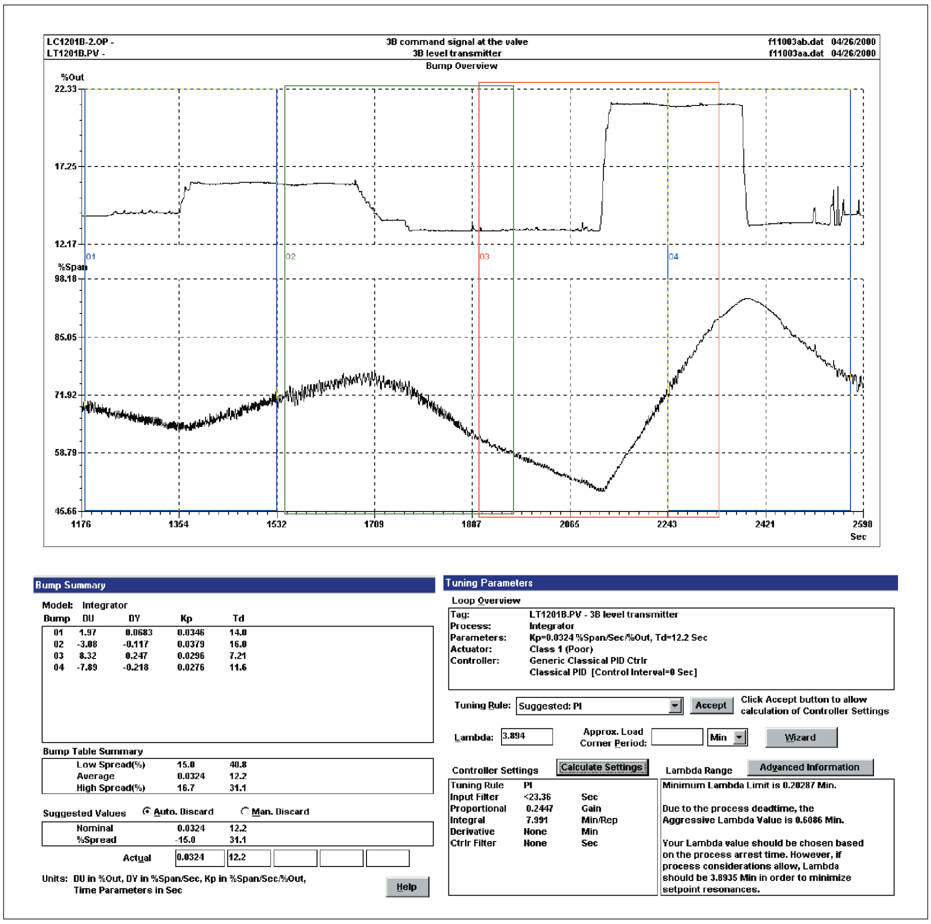

Fig. 5. Loop performance and calculated loop tuning settings

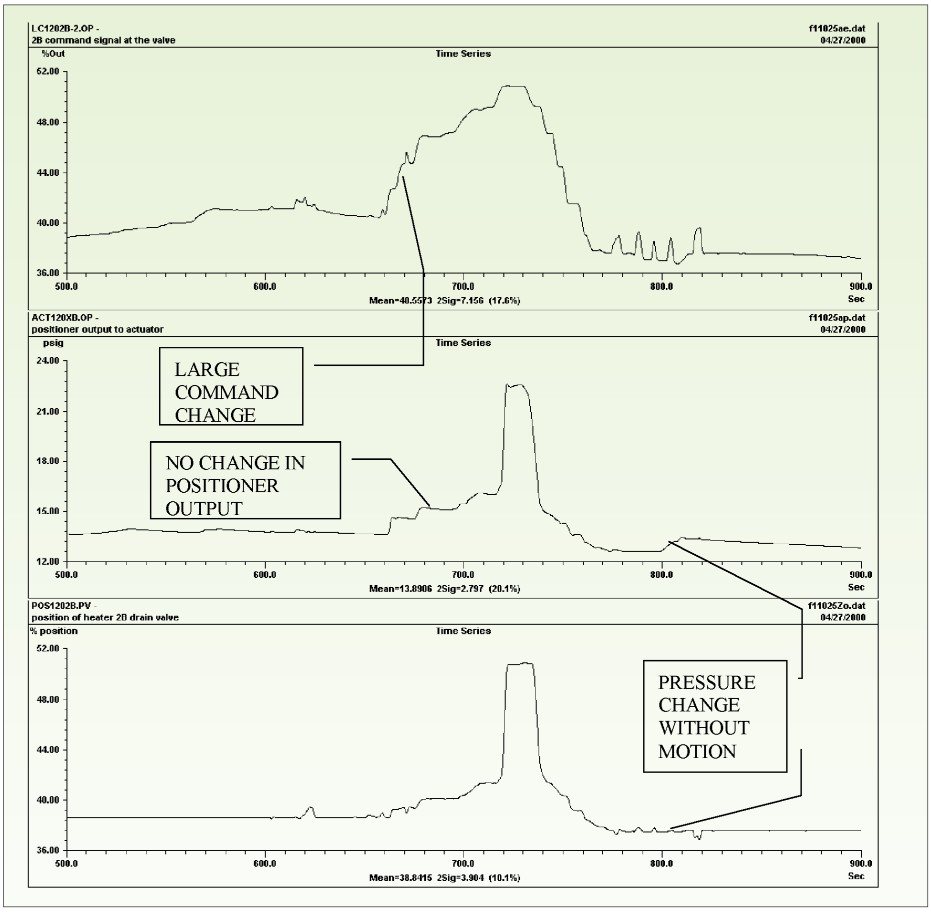

Fig. 6. Valve performance on heater 2B

curves in the circled areas to get a better feel for what is happening (Figure 4).

As you can see, for only a 0.5% step, it takes the valve 4.5 seconds to respond on the upstroke and 2 seconds to respond on the downstroke. This doesn't sound like much unless we consider how far the level could swing in those 4.5 seconds when the valve is not moving at all. All the time, the controller is seeing a bigger and bigger deviation from its setpoint and continues to change the output to the valve waiting for something to happen. When the valve finally moves, the command signal has already gone well past where it needs to be, and the whole process has to start over again in the opposite direction. This is commonly called a limit cycle, and it sets up cyclic behavior in heater levels, which is something we want to avoid.

Another important step in the process is to evaluate how the whole loop performs and then to determine optimum tuning parameters as a result (Figure 5). In this case, the valve position is plotted next to the level reading allowing such characteristics as gain, time delay, and time constants to be calculated.

Without going into too much detail, suffice it to say that the recommended tuning parameters to gain maximum performance (minimum heater level swings) are outside the operating range for a pneumatic controller. Nothing one could do with existing controller will bring the loop into state of the art performance. The heater levels will not be well controlled given the current setup.

To summarize this situation, the valve is much too slow to give the loop a chance to operate properly, and the controller is incapable of providing optimum response. Both of these key loop components need to be changed out for more modern equipment. The valve and positioner combination that was suggested cuts the lag time by an order of magnitude, and a modern electronic single loop controller can be tuned perfectly to the recommended settings noted above to cut the level swings to something less than 1%. State of the art process control systems routinely deliver less than 1% error between the process variable and the setpoint. If a plant is seeing more than this, they should include the offending loop in their process audit work.

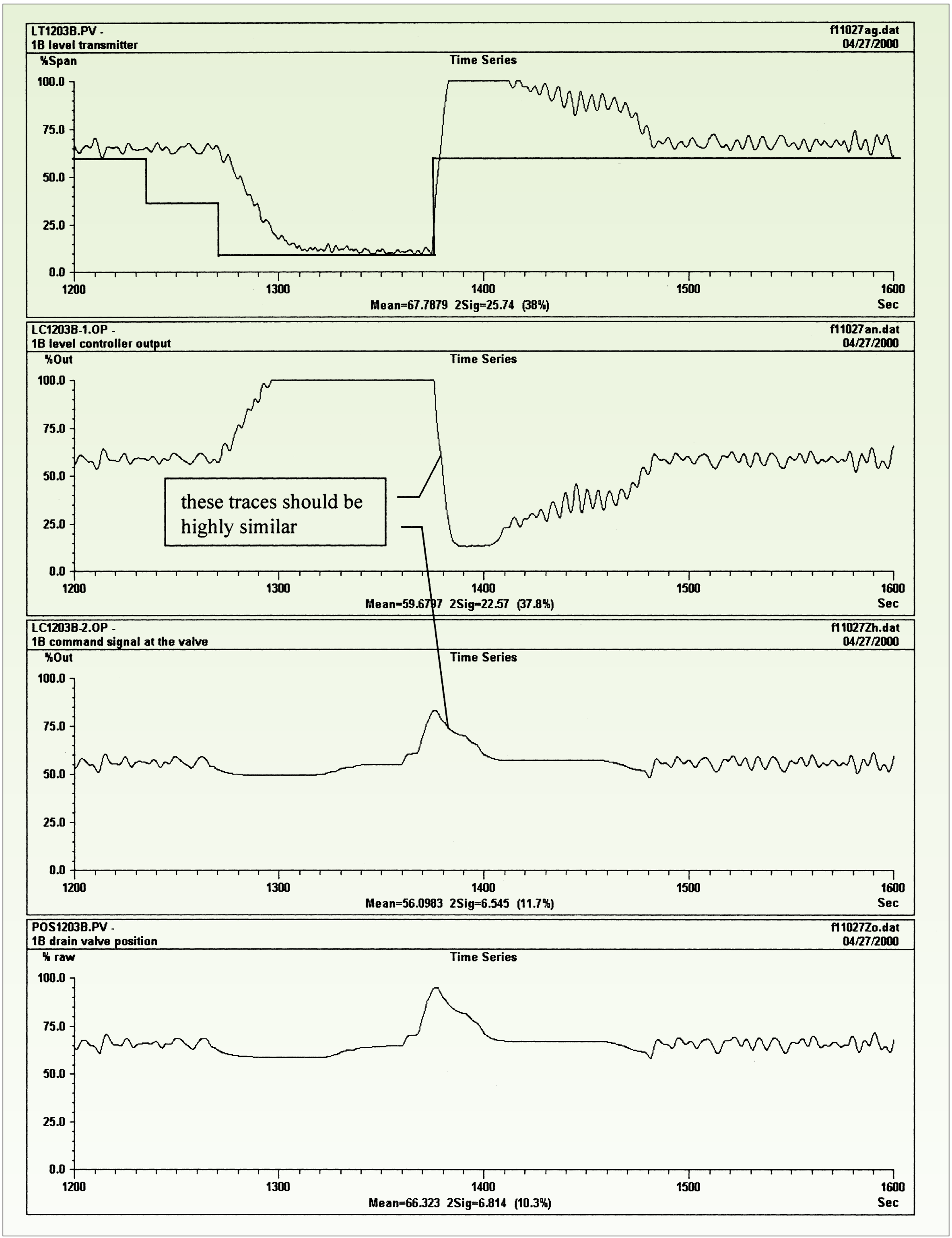

Fig. 7. Total loop response on heater 1B

Heater 1B

This heater was characterized as having high flows (e.g., 1000gpm), and was only four feet in diameter. The process control response was particularly critical here since small control errors could result in very large level swings. The time lag was measured to be 1.5 seconds for the valve and positioner combination. While the lag doesn't sound like much, given the physical characteristics of this heater, it is too large. A "booster" is recommended for this valve to speed up the stroking speed. For this system, we plotted level, controller output, command signal at the valve, and valve position while we changed the setpoint three times while in automatic mode (Figure 7).

The above curves show a loop and system that are in very poor condition. The level routinely swings 15% every 10 seconds or so. The controller output does not match the setpoint changes. The command signal at the valve and the controller output do not agree, and they should. Note that very little happened to the valve positioner even though the setpoint changed by over 20%!

To clean up this performance, the controller needs replacement and both the positioner and valve need to be either replaced and/or worked on.

Heater 2B

The same swings were seen in this heater as well. A slightly different type of test was done to see if the root cause could be tracked down. In this case, we plotted the command signal from the controller against the output pressure from the valve positioner and against valve position (Figure 6). These curves tell us that there is very poor tracking between the three signals. This means that the positioner is not operating properly and the valve appears to be sticking. Both of these components need either to be serviced or replaced. Once this is done, a new controller needs to be installed that will once again permit the tuning settings we need for optimum operation.

Financial Justification

Now for the $64,000 question. How much is this going to cost me, and what will I get back in return?

From a budgetary standpoint, it has been estimated that the recommended upgrades to all six heaters will roll up to about $384,000 over a two-year period, including both capital and related expenses. The payback has been figured over a five year period and includes the following economic benefits:

- Increased efficiency: The proper operation of all heaters at the plant should increase efficiency by anywhere from 0.5 to 1.0%. This results in a savings on fuel of about $300,000/year. The whole upgrade program would be nearly funded just on fuel cost savings for the first year!
- Smoother operation of the heaters will permit regular operation of the plant at closer to the physical limits with a reduced chance of a trip. We conservatively estimate that at least one more MW could be generated from the plant, all other things being equal. If we assume a fuel cost of $4.7/MW-HR and a normal sales price of $55/MW-HR, this means that the plant could pocket another $420,000 in annual revenue based on the size of the plant and availability figures.
- Reduced maintenance costs: The plant puts the heaters at the top of the list when it comes to maintenance expenditures. They estimate that they spend over $100,000 per year to keep these systems up and running. Based on smoother operation, we should be able to cut these costs in half.
- Reduced trips due to heater instability impacting hotwell levels: The plant estimates the cost of a trip to be in excess of $1million in terms of lost revenue and real costs associated with re-start. If the heaters contribute at a 10% annual rate to the trip probability, and we can cut this in half, the expected cost reduction associated with smoother operation comes to $50,000/year.
- Improved reliability: While of a softer nature, a performance improvement in the heaters will improve availability for the plant, which is an important element of overall operation.

To summarize, the recommended upgrades to the process control infrastructure will cost $384,000 over a two year period, and should deliver a very conservative $570,000 in annual positive cashflow over the duration of the project, which we have selected to be five years. These figures translate into a net present value of over $1.6 million and an internal rate of return of over 100%. This would easily clear nearly every corporate hurdle rate that might exist. Overall, this should be a very positive project.

raising heater efficiency may translate into fuel savings of $300,000 per year.

Conclusion

What we have shown is one example of the kinds of economic benefits that can accrue for a nuclear power plant by undertaking a proactive and systematic approach to improving process control performance. Heaters are a good place to start, as they tend to be bad actors and we can easily tie plant performance parameters to their performance.

However, many more opportunities exist within the plant, so the potential for further economic gains is huge. There will also be synergistic affects as each improvement plan builds on the prior work, making the potential returns even larger in relation to the investment required.

The good news is that none of this is rocket science. The approach employs tried and true techniques and hardware that have been in use in other industries for more than 20 years. It does take a new attitude towards how we operate our plants and how we leverage new developments. This may be the biggest challenge, the changing of our conservative culture. But, if we are to remain a viable alternative in the power industry spectrum, change will have to happen. ■

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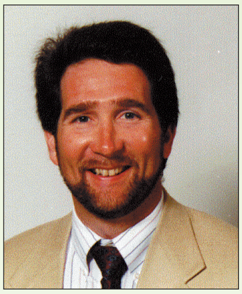
About the author



Bill Fitzgerald graduated from Iowa State Univ. in 1975 with a BSME and immediately went to work for Fisher Controls in Marshalltown, Iowa in the Design group. He spent 5 years there before moving to Fisher's manufacturing plant in Cernay, France as a technical liaison with the main engineering group back in the states. After 4 years overseas, he returned to Marshalltown for 2 years as Marketing Manager for the Power Industry, before transferring to Columbia, SC as the General Manager of Fisher Service Center covering the Southeast. At about that same time he completed his Master's in Engineering Mechanics, again at Iowa State. He ran the service center in South Carolina for 3 years and then transferred to Mckinney Texas after inventing a valve diagnostic tool called the FlowScanner aimed at detecting and predicting operational problems with control valves. He headed up the diagnostics group until the fall of 1994 when he was named as the End-user Marketing Director for the service division. He was named Global Business Director-Power for Performance Services in the summer of 1997 and held that position until May of 1999. At that time, he was named Operations Director for the Engineered Products group and still holds that position. He earned an Executive MBA degree from SMU in Dallas in the spring of 1998. He makes his home in Marshalltown. He has written many articles and made countless presentations on control valves and control valve maintenance, and in 1994 he completed his first book entitled "Control Valves for the Chemical Process Industries".

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