

Innovative control technique improves control rangeability and resolution in paper mill applications

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ABSTRACT: *The power of a modern digital controller allows innovative control strategies to be implemented. This article discusses one such strategy that has been used successfully in several paper mill powerhouses. It may be applied where a controlled parameter is maintained by manipulation of two final control elements. It has been used to improve two-valve pressure-reducing valve header pressure control, recovery boiler black liquor flow control using a variable-speed pump and valve, furnace draft control using a variable-speed fan with a damper, and forced-draft fan pressure control using a variable-speed fan with inlet vanes. Many other applications are candidates for this strategy, such as bypass control on the headbox and consistency control for high-density storage. The strategy provides good control resolution and immediate response to large demand changes. This strategy and its applications illustrate how advanced control may be implemented to provide improvement over traditional approaches.*

KEYWORDS: *Control systems, controllers, digital control, paper mills, process control, technology, utilization.*

Many process installations with state-of-the-art control hardware have not fully exploited the potential of their systems to improve control and thus lower production costs. Simply transferring long-established analog controller strategies to a distributed control system (DCS) does

not tap the true power of that system. However, using the power available in a modern digital controller allows innovative control strategies to be designed and implemented. These strategies are limited only by the talent and imagination of the designers. One such strategy has been used for a

variety of applications in the paper mill powerhouse, and it can be applied to other applications throughout the pulp and paper mill.

Occasionally, a process control application will require a process variable to be controlled by manipulating two final control elements together. **Figure 1** shows three examples: two pressure-reducing valves in parallel, a fan damper in series with a variable-speed fan drive, and a pump in series with a throttling valve.

In the past, the control achieved was typically less than optimal because the available control technology limited the complexity of practical strategies. In 1983, a new solution to this control problem was devised that utilized the advanced control capability of the digital controller in a DCS. This strategy has been used in several pulp and paper mills. The first application was to maintain pressure on a large steam header by manipulating two pressure-reducing valves (PRVs).¹ Another application was control of forced-draft fan pressure through manipulation of a variable-speed forced-draft fan and the fan damper. The control of furnace draft was similarly improved with an induced-draft fan drive and damper. The most recent application was to improve flow con-

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¹Originally discussed in "Improving PRV Pressure Control" by Terry Blevins (Paper 85-0256: Instrument Society of America, 1985).

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trol of strong black liquor to the firing guns of a recovery boiler by manipulating a variable-speed pump drive and a throttling valve.

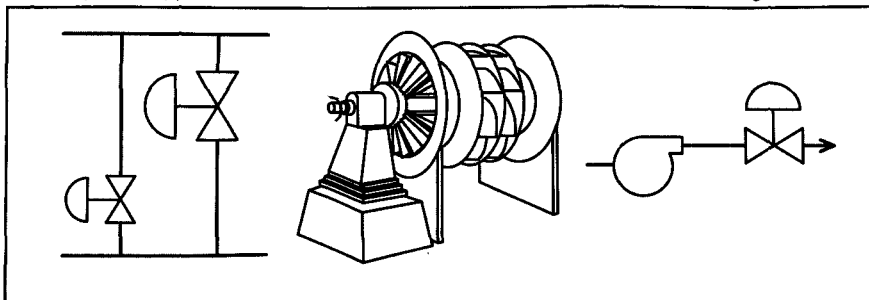
PRV control problems and traditional solutions

The steam header pressure in many mills is maintained by adjusting PRVs to accommodate fluctuating process steam demands. Often a large, high-flow valve is used in parallel with a smaller, low-flow, high-resolution valve. **Figure 2** shows a case where the header is supplied by turbine generator extractions and two PRVs. The turbine extractions are often automatically regulated by the turbine controls to maintain constant header pressure. The PRVs are manipulated together to control the header pressure when the extraction cannot meet the steam requirements of the 450-psi header. This is accomplished by the PRV controller setpoint being set lower than the extraction target pressure.

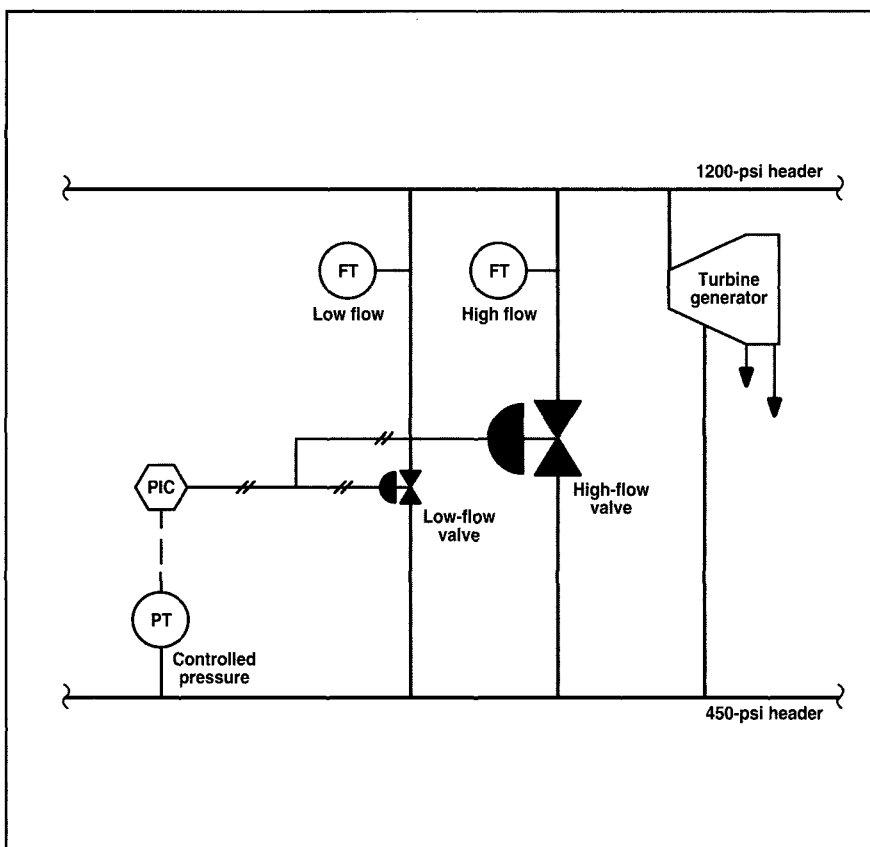
Usually, for automatic control, either split range control or valve position control² is the strategy used for the PRV controller. Both use the output of a PID pressure control loop to manipulate the two valves together. The choice of which strategy to use involves a tradeoff between dynamic response and control resolution. The goal of the new strategy development was to combine the desirable features of these two strategies and eliminate that tradeoff.

The header is fed by extractions from a turbine generator and two PRVs, and it provides process steam to other areas of the plant. A PID pressure controller maintains target header pressure by adjusting the PRVs when the extraction cannot meet 450-psi steam requirements. Under optimal conditions, these PRVs stay closed, and all process steam is obtained from generator extractions. However, when the

1. Examples of applications where two final control elements are manipulated together



2. Steam header process

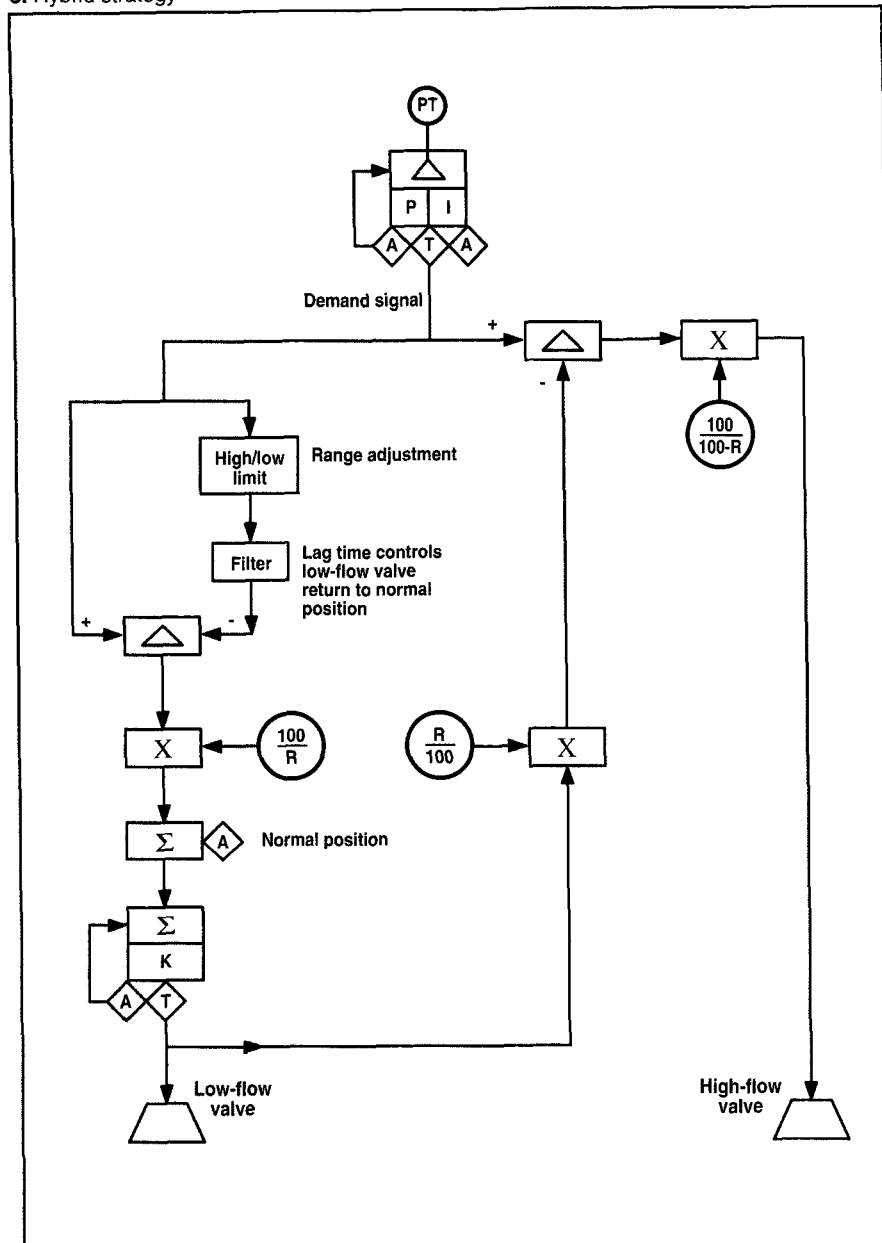


generator extractions are insufficient, the PRVs must be opened and adjusted to supply the additional steam and to maintain header pressure. When the pressure sags and more steam is required, the demand increases, and vice versa. (As used here, "demand" refers to the output of the pressure controller, which is used to adjust steam flow into the header by manipulating the PRVs.) Due to fluctuations in generator extractions and the process steam required by other plant areas, the demand can shift over a wide range. How-

ever, the header pressure must be maintained as tightly as possible during adjustments. The need for tight control over a wide range suggests using a parallel combination of a large, high-flow valve and a small, high-resolution valve. Traditionally, the two techniques used to manipulate two valves together are *split range control* and *valve position control*. Each of these strategies meets one objective better than the other.

With split range control, the low-flow valve is adjusted as the controller

²Readers interested in these topics should consult articles and books by F. G. Shinskey, particularly the ISA Learning Module (book) *Controlling Multivariable Processes*.



output varies between zero and R , where R is the ratio of the low-flow valve's capacity to the sum of the high-flow valve and low-flow valve's capacity. A typical value of R might be 25%. When the controller output goes above R , the low-flow valve stays fully open as the larger valve is used. The benefit of using this strategy is that the system responds immediately to a large demand increase. However, the drawback here is that once the demand exceeds the low-flow valve's capacity, that valve stays open, and the high-flow

valve is used to adjust the flow; this yields much coarser control resolution.

With valve position control, the low-flow valve is returned to and maintained at a normal position when the demand is steady, regardless of what that demand is. When a small demand change occurs, the low-flow valve is adjusted. With this approach, the fine control resolution is available at any demand level, unlike split range control, which provides it only at the low end. However, when the demand change exceeds the capacity of the low-

flow valve, the response of the high-flow valve is limited to the reset rate of an integral-only controller, whose output directly adjusts the high-flow valve. This reset rate is tuned to be slow in order to avoid interaction.

Advanced control strategy

A strategy has been developed that combines the full, immediate response to large load changes provided by split range control with the good full-range resolution provided by valve position control. The algorithm (Fig. 3) was implemented in a DCS using digital controller function block language. For simplicity, the logic and calculations for bumpless transfer on controller mode changes are not shown in the figure. In normal operation, the pressure controller and bias/gain station are in automatic mode.

As is the case with valve position control, the smaller, higher-resolution valve is maintained at a normal position during steady demand and is used to make the initial adjustment for a small demand change. However, unlike valve position control, when the demand change exceeds the capacity of the low-flow valve, the high-flow valve is immediately engaged and adjusted. In either case, when the demand is steady, the low-flow valve is slowly returned to its normal position, while the high-flow valve is slowly adjusted to satisfy the demand and maintain header pressure. Thus, the strategy matches the good full-range resolution of valve position control for small demand changes and the full, immediate response of split range control for large demand changes.

The rangeability, R , is an empirically determined parameter used in the scaling blocks. These blocks provide the same change in steam flow for a given change in demand for all operating conditions. R is determined by making a percent change in the position of the low-flow valve and observing the change in steam flow F_1 , making the same percent change in the position of the high-flow valve and

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observing the change in steam flow F_H , then calculating R as follows:

$$R = [F_L / (F_L + F_H)] \times 100 \quad (1)$$

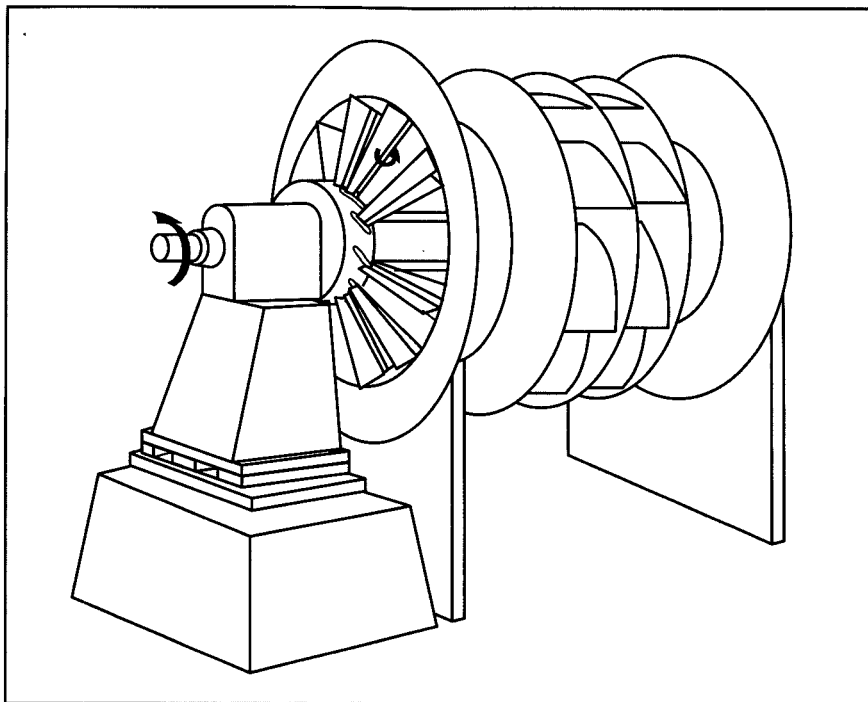
The low-flow valve is returned to its normal position by the circuit containing the signal limiter, filter, and difference blocks. The purpose of the filter is to lag the demand signal it receives. That lag in demand is input to the difference block, where it is subtracted from the unlagged demand. On a demand change, the signal from the subtraction block is initially equal to the demand change. After the elapsed time exceeds several filter time constants, that signal goes to zero. This signal is scaled, summed with the low-flow valve's normal position, and sent to the bias/gain station that positions the low-flow valve. Thus, on a small demand change, the low-flow valve is adjusted to meet the change. As time passes and the output of the filter reaches the new demand, the low-flow valve is reset to its normal position.

The high and low limits of the signal limiter preceding the filter are the parameters that determine the steady demand levels at which the low-flow valve stays open or closed more than the normal position. These limits must be calculated based on the rangeability R and the normal position. These limits allow the low-flow valve to be closed or fully open when the large valve is closed or fully open.

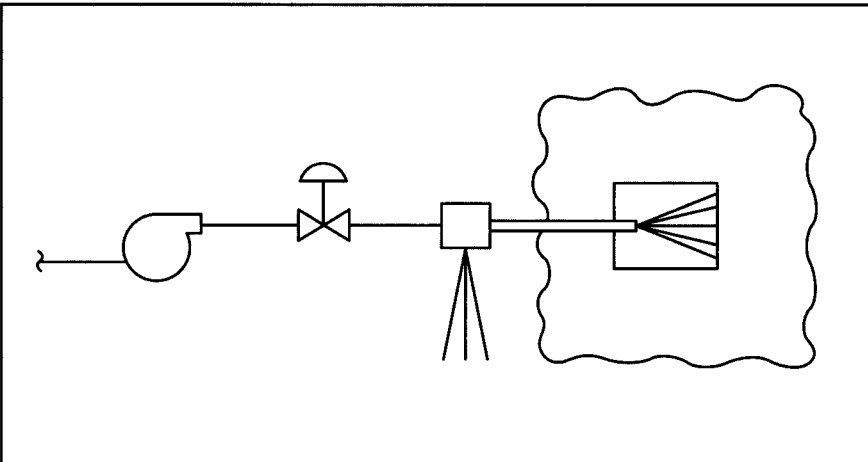
Other applications

The application of this strategy to any control problem requiring manipulation of two final control elements (to maintain one controlled parameter at setpoint) is very straightforward. It requires almost no modification of the basic algorithm. The strategy design and application to the PRV problem were done in 1983. The strategy was recently applied to control forced-draft fan discharge pressure and furnace draft. In these cases, the high-capacity elements were the variable-speed drives to the forced-draft and induced-draft fans, and the high-resolution el-

4. Forced-draft fan control



5. Black liquor-to-guns flow control



ements were the fan dampers. This technique was also recently applied to the flow control of strong black liquor to the firing guns of a recovery boiler, using a variable-speed pump and a throttling valve.

Forced-draft fan furnace pressure and furnace draft control

Figure 4 shows a forced-draft fan whose variable-speed drive is being controlled with the position of the in-

let vanes. When a large forced-draft fan is controlled with a variable-speed drive, there are two reasons why inlet vanes may be beneficial: rangeability and control resolution. The flow may need to be reduced below the flow rate existing at minimum speed, so the inlet vanes extend the control range. Furthermore, if the flow must be continually varied, the vanes are much better suited for such manipulation and may provide faster response than the variable-speed drive. Within the

context of the basic control problem, the variable-speed drive and the inlet vanes are analogous to the high-flow and low-flow PRV valves, respectively. The same concept can be applied to furnace draft control using a variable-speed induced-draft fan with damper.

Black liquor-to-guns flow control

The flow of black liquor to the firing guns of a recovery boiler is usually regulated by adjusting a variable-speed pump (Fig. 5). Regulation with a valve is usually avoided because the liquor temperature is near the flash point and because the liquor contains abrasive material that can erode the valve. However, in some installations, the liquid head required is so high that the flow cannot be sufficiently reduced at minimum pump speed, and a throttling valve is required. Typically, when this is done, the valve is maintained at some position until the pump reaches minimum speed, at which point the valve is manually adjusted to reduce the flow. When both a variable-speed drive and a valve are provided on the process, the manipulation of these two elements has been improved by using the advanced automatic control strategy discussed above.

Concluding remarks

The hybrid strategy described here is a straightforward example of the advanced capability of digital controllers. Originally developed in 1983 to improve header PRV control, it has been successfully transferred to many other applications. There are many other control problems to which this control strategy could be applied, including such challenging applications as bypass control on the headbox and consistency control for high-density storage.

The continual evolution in the technology of user interfaces, communications, I/O (input/output) systems, and controller capability has reshaped process control, but in many installations, much of the real potential for process improvement remains un-

tapped. While most industrial process installations have the latest hardware, the utilization of controller capability varies widely. Dramatic improvements in control can be achieved by taking advantage of the advanced control capability available with today's digital controllers. □

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