YVP110 ADVANCED VALVE POSITIONER

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YVP110 is a valve positioner conforming to FOUNDATION™ fieldbus standard. YVP110 maintains high reliability by using a non-contacting position sensor and a newly developed small I/P module. Compared with conventional analog-mechanical positioners, YVP110 demonstrates dramatically enhanced functionality and improved positioning performance, achieved by valve diagnostics and a nonlinear compensation control algorithm. This document describes the features of YVP110 plus its superior controllability and maintenance ability, which contribute to reduced plant operation costs.

INTRODUCTION

The environment surrounding the process plant industry has changed dramatically because of the recent economic changes, deregulation, and increasingly fierce competition among global companies. Users are strongly requesting instrumentation equipment vendors to reduce total cost throughout the life cycle and help improve the efficiency of plant operation.

Under these circumstances, some FOUNDATION™ fieldbus-enabled field devices and DCSs have been commercialized by Yokogawa since 1998. What users expect most from the use of network technology is reductions in costs involved in the operation of final control elements (control valves, including positioners)—the most important elements in a plant—and other relevant peripheral devices.

The following approaches were taken to deal with the subject of such operation cost reductions in the case of the YVP110 advanced valve positioner (Figure 1)—a device jointly developed with Dresser Flow Control, the world's second largest manufacturer of control valves under the Masoneilan brand.

(1) Attainment of long-term reliability
This means ensuring long-term operational stability and durability by adopting a small-sized I/P (current-to-pneumatic transducer) module and a non-contacting displacement sensor.

(2) Improvement in dynamic characteristics
This means improving the capability of tracking small signals and dynamic characteristics, such as overshoots, by using a nonlinearity-compensating valve control algorithm. These improvements are made in order to help upgrade the performance of plant control systems and thereby the quality of process products.

(3) Addition of diagnostic functions
This means further installing on-line/off-line valve diagnosis functions, in addition to the self-diagnosis functions of the positioner itself. This installation is implemented in order to

Figure 1 YVP110 Installed in Actual Plant
(by courtesy of the Fushiki plant of Nippon Paper Industries)

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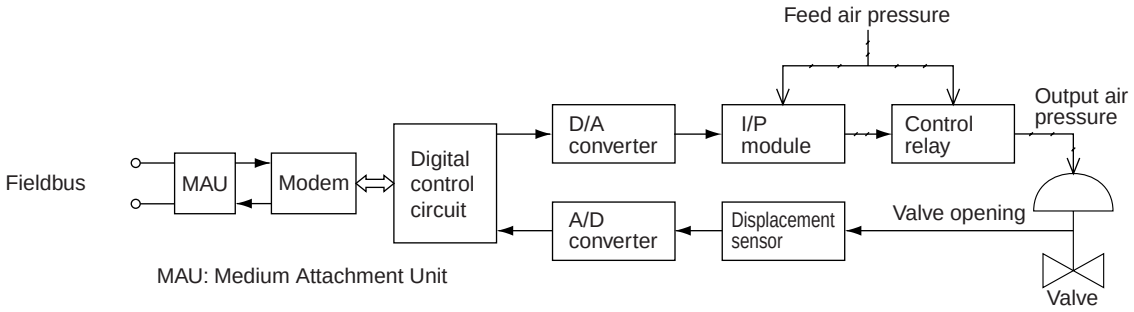

Figure 2 Block Diagram of YVP110

help reduce maintenance time and perform preventive maintenance.

(4) Facilitation of installation
This means adding auto-tuning functions for measuring valve characteristics to determine parameters. This also means developing human-machine interface (HMI) tools and thereby reducing the installation time.

In the following discussion, we will focus on what the YVP110 brings to users, as well as discuss our prospects regarding the future development of advanced valve positioners.

FEATURES OF YVP110

Figure 2 is a block diagram of the YVP110. The valve opening is detected by the displacement sensor. The result of valve control computation is converted to pneumatic pressure by the I/P module and then amplified by the control relay. The YVP110 advanced valve positioner features:

(1) Small-sized and lightweight construction
We have thoroughly slimed down the building blocks of the YVP110 by downsizing the I/P module and densely integrating the electronic circuitry using dedicated ASICs. This effort helped improve the vibration resistance characteristics of the valve positioner installed in place (specified as 4 mm at 5 to 15 Hz and as 2 Gs at 15 to 2000 Hz). The YVP110 weighs only 2.3 kg, the world's most lightweight valve positioner as of March 2001, compared with those of the same class.

(2) Reliable, non-contacting displacement sensor
All electrical contacts and sliding parts of the sensing element were eliminated from the displacement sensor that holds the key to high reliability. Alternatively, a method was adopted for detecting changes in mutual inductance in a non-contacting manner. This displacement sensor helped eliminate backlash and hysteresis that were unavoidable with the conventional contact-based method, thus increasing the accuracy of the YVP110. Furthermore, a sufficient level of durability was ensured for repetitive actions, as well as for continuous, marginal changes in the input level at and around a specific degree of valve opening.

(3) I/P module
The newly developed miniature I/P module features lightweight design, as the weight of moving parts was reduced to 0.5 g, 1/200 the weight of our earlier models, by constructing the flappers with metal diaphragms. At the same time, the number of anchor points fixing the flapper was reduced to simplify the module structure. This design ensured reliability to the degree that the module operates stably over a prolonged period even under such severe disturbances as heat cycling or vibration.

(4) A wealth of functions
The YVP110 is provided with a wealth of functions that any conventional analog mechanical valve positioner could never offer. These functions include:

- a valve opening signal monitor
- a valve output pressure signal monitor (optional)
- the capability to change flow rate characteristics (process gain optimization)
- a tight shut-off function (compatibility between controllability and tight shut-off)
- auto-tuning (automatic adjustment of the zero/span and control parameters)
- integration of the valve's operation state parameters

(5) Function blocks
The following four function blocks were installed in the YVP110.

- Analog output (AO) block
- Discrete input (DI) blocks (two; designed for limit switch function)
- PID block (optional; designed for process controller function)

If these function blocks are combined with an AI block on the sensor side, it becomes possible to configure a control loop without the need for any controller. Note that the YVP110 was the world's first valve positioner to pass the ITK4.0 interoperability test compliant to the latest FOUNDATION™ Fieldbus standard.

IMPROVED CONTROLLABILITY

The performance of a control valve is extremely important in

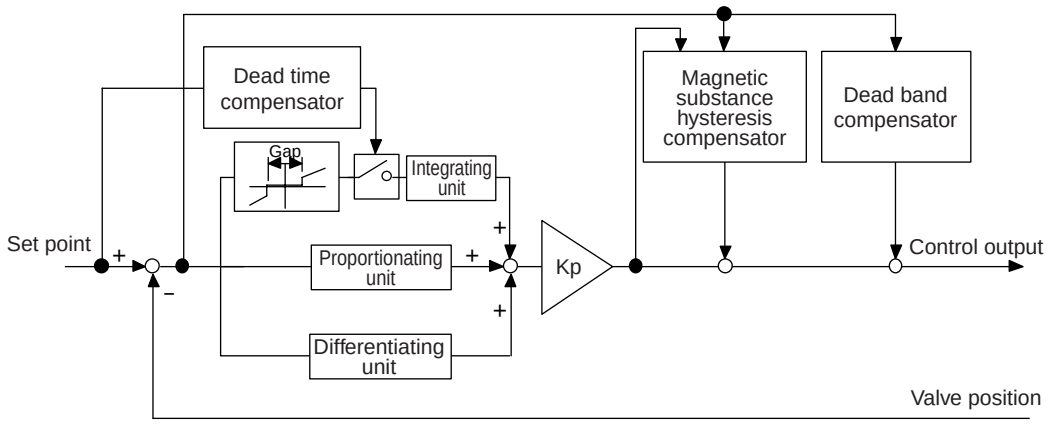

Figure 3 Block Diagram of PID Control with Nonlinearity Compensation

order to ensure stable plant control and operation, minimize the variability of a process product, and thereby improve quality and efficiency.

The dynamic characteristics of the control valve, such as the response, dead time for small signals and overshoot, are especially critical, as they will significantly affect the quality of the control loop.

Nevertheless, valves and the mechanical elements (I/P module and control relay) of a positioner include hysteresis, dead bands and other nonlinear factors. For the YVP110, we have developed a control algorithm for compensating these nonlinear factors (Figure 3). Consequently, we attained dynamic characteristics that enable regularly used valves to keep track of signals as small as 0.1% or less. Figures 4 and 5 show the presence/absence of the effect of nonlinear compensation for a case where the same PID parameter is used.

The positioner is also provided with the auto-tuning function for optimally tuning the control parameters of a variety of valves. This function is designed so that valve characteristics are measured on the positioner side to determine the control parameters.

IMPROVED MAINTAINABILITY

What users expect most from valve positioners in networking of the field are reductions in operation costs through improved maintainability. In addition to the self-diagnosis function of the positioner itself, the YVP110 is provided with the function for diagnosing valves that are most vulnerable yet extremely important in a plant. The valve diagnosis function is roughly classified into on-line and off-line diagnoses.

(1) On-line diagnosis

The following state parameters of valve operation are integrated within the positioner.

- Open and closed times
- Nearly-closed time
- Amount of positional displacement and number of cycles

Although the service life of a valve varies depending on actual operating conditions, the time of valve maintenance can be optimized by accumulating data. For example, the nearly-closed time is obtained by integrating lengths of time during which the degree of valve opening is marginal and

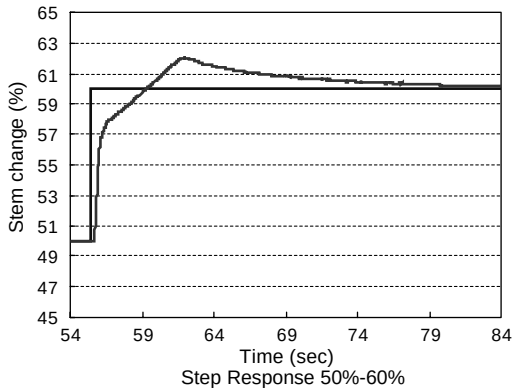

Figure 4 Response Characteristics of Normal PID Control

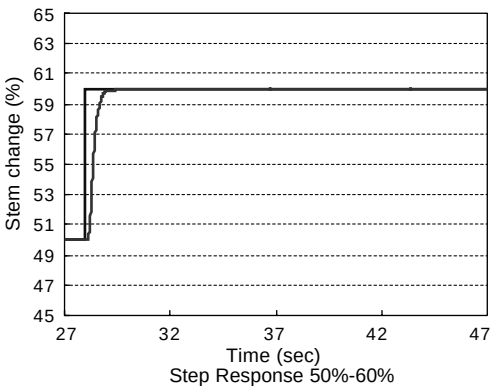

Figure 5 Response Characteristics of PID Control with Nonlinear Compensation

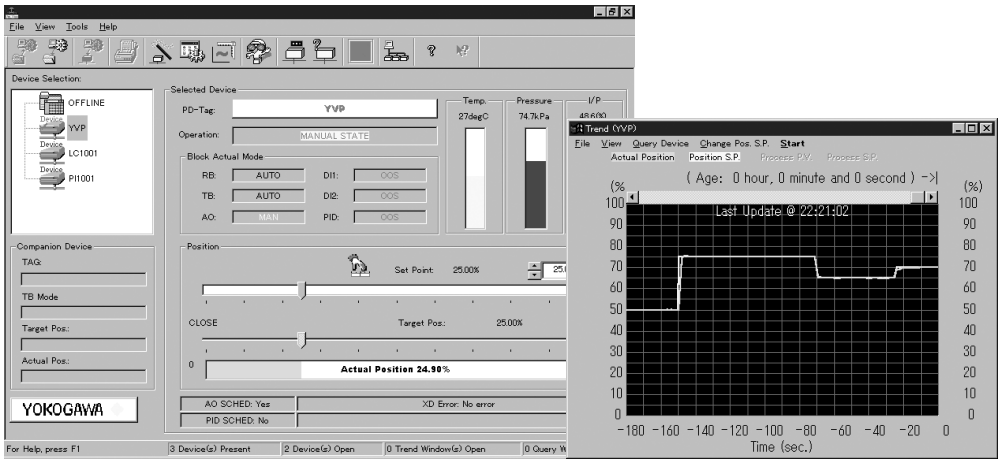

Figure 6 Example of ValveNavi Screen

therefore the flow velocity is high. This state parameter is expected to be effective for predicting erosion.

(2) Off-line diagnosis

The following valve-related physical parameters and the loop gain of a control system are measured when auto-tuning or self-check is performed.

- Values proportional to valve actuator capacity
- Hysteresis and stick-slip width
- Range of valve operation pressure

By measuring these parameters at each time of periodic inspection, it is possible to detect changes in valve characteristics. Easy comparison can be made with parameters obtained earlier by using the database function of Plant Resource Manager, an integrated device management package provided by Yokogawa.

(3) Future development of diagnostic capabilities

As the next step toward advancing the YVP110, we are developing a function for signature analysis, an extended version of the off-line diagnosis functions. This function is designed to measure the below-listed characteristics within the positioner and internally store data on the measured characteristic curves.

- Valve's I/O characteristics (pressure vs. valve opening)
- Valve's step response characteristics (time vs. valve opening)
- Positioner's I/O characteristics (setpoints vs. valve opening)

Thus, the function will allow for in-depth diagnosis by comparison with earlier characteristics.

USER INTERFACE

In order to make the most of the YVP110's wealth of functions and provide users with superior human-machine interfaces, we are developing ValveNavi (Figure 6), the Windows-based, dedicated management software. The major functions of this human-machine interface include:

- Administration (user-by-user operational restrictions)
- Change in operation mode (Normal, Manual and O/S)
- Change in device tag and node address
- Trend and bar-graph views
- Setup Wizard function
- Parameter change
- Display of diagnosis results
- Faceplate-format view of PID blocks
- Settings report function (output as an *.html* file)

At the time of initial setup after mounting the positioner on a valve, it is possible to complete all the basic settings of the positioner by simply selecting Setup Wizard from the menu and executing it. Since the interface supports trend screens, it is also possible to adjust a valve while observing a waveform representing the actual valve opening.

CONCLUSION

In this article, we have discussed the YVP110 advanced valve positioner, focusing on its features and improvements in controllability and maintainability. We have improved the YVP110 dramatically in its functionality and performance, compared with conventional analog-mechanical positioners, while maintaining the required reliability level. In the future, we will further enhance the diagnostic capabilities by installing such functions as signature analysis, in order to help reduce users' total cost throughout the life cycle. ◆

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