Understanding the benefits of using a digital valve controller

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Evolution of Valve Positioners

- Analog (Electro-pneumatic / Pneumatic)
- Digital (Next Generation)
- Digital (First Generation)
Analog vs Digital Valve Positioners

Definition

• Analog
  - Does not include a microprocessor
  - Mechanical or electro-mechanical feedback and control.

• Digital
  - Includes a microprocessor
  - Various types of sensors measure the valve position and possibly actuator pressure to position the device.
Configuration / Calibration
Analog vs Digital Positioners
Analog Positioners

Configuration

• Mechanical configuration of the device...
  - Cam moved to a defined position, side, or even replaced/modified
  - Potential adjustment of spring positions
Analog Positioners
Calibration

• Zero (i.e. close) and Span (i.e. open) are manually adjusted during calibration. These positions often affect each other requiring you to go back and forth adjusting each one multiple times.

• Verifying performance is difficult and ideally requires the use of an external test system to measure the position and test its response.
First Generation Digital Positioners

Configuration / Calibration

• Either required the use of an expensive external configuration device or if a basic user interface was included it often required a complex user manual to use properly.

• Calibration often required manual PID tuning
Next Generation Digital Positioners

Configuration / Calibration

• Large local user interface with capacitive buttons
• Guided startup wizard greatly simplifies configuration and calibration.
• Calibration and tuning are fully automated
Wear & Vibration Tolerance
Analog vs Digital Positioners
Analog Positioners

Wear / Vibration

• Mechanical feedback parts can wear or seize over time

• Physical connection to the actuator (especially with linear applications) can wear over time.
First Generation Digital Positioners

Wear / Vibration

• Typically used a contacting position sensor which would wear / break over time.

• Physical connection to the actuator (especially with linear applications) can wear over time.
Next Generation Digital Positioners

Wear / Vibration

• Fully Contactless valve position sensing, eliminates any shaft or sensor that could wear over time.
Control Advantages
Analog Positioners

Proportional only control:
Beams, levers, springs, cam.
Proportional only control:

The positioner will not correct for any offset after the initial movement.
Smart Digital Positioner

\[ \left[ m_{\text{red}} \cdot \frac{d^2 x}{d\psi^2} + J \cdot b(\psi, \mu) \right] \cdot \frac{d^2 \psi}{dt^2} + m_{\text{red}} \cdot \frac{d^2 x}{d\psi^2} \cdot \left( \frac{d\psi}{dt} \right)^2 + \left[ f_m \cdot \frac{d x}{d\psi} + f_v \cdot b(\psi, \mu) \right] \cdot \frac{d\psi}{dt} + \text{sign} \left( \frac{d\psi}{dt} \right) \cdot b(\psi, \mu) \cdot M_{v\mu}(\psi, \mu, \Delta p) + b(\psi, \mu) \cdot M_d(\psi, \Delta p) - F_m(P_A P_B) = 0 \]

Advanced control algorithm:
Based on detailed mathematical study of control valve dynamics.
Accurate Valve Control

Nonlinearities due to friction
Advanced Control Algorithm

Reduces dead time and overall response time

Advanced control algorithm corrects for frictional effects:
- Algorithm learns static friction levels
- Pressure “boost” breaks static friction quickly
- Continually updated during operation

![Graph showing control signal with and without advanced control algorithm]
Advanced Control Algorithm
Reduced process variability

Digital Positioner

3.3 psi

101 gpm

Digester Pressure

Flow

18:00 13:30 19:00 19:30 20:00

Analog Positioner

9.7 psi

214 gpm

Digester Pressure

Flow

11:00 11:30 12:00 12:30 13:00

Black liquor make up, continuous digester
Installed Flow Characteristics
Valve & Process Characteristic

**Linear:**
A flow characteristic in which the valve relative opening directly correlates to the percentage flow, e.g. a 50% open valve gives 50% of maximum flow, with a constant pressure drop across the valve.

**Quick Opening:**
A flow characteristic in which a flow close to a maximum flow is reached with a very small valve opening.

**Equal Percent:**
Equal increments in the valve opening cause a constant percentage increase in flow with a constant pressure drop across the valve.
Installed Characteristic and Gain

- Describes the control behavior of a valve when it is operating in the process.
- Installed characteristics is an important indication of controllability.
Linearization of Installed characteristics

Positioner capabilities

- Proper valve selection for the application is critical but of course no valve has a perfectly linear installed flow characteristic.
- The positioner can compensate for this non-linearity by adjusting how much the position changes versus the set point.
- **Analog** positioners can do this with a custom cam which is engineered for the specific application/valve.
- **Digital** positioners can do this by programming a signal modification curve based on the valve sizing.
Diagnostics
Analog Positioner

Diagnostics

• In the 80’s, external systems were developed to allow for accurate data collection by controlling the setpoint and monitoring the valve position and pressures. Today these systems are still used to validate the health of brand new valve assemblies as well as verifying the valve condition after a repair.

• Industry standards, such as ISA S75.13, emerged to define procedures for testing and analyzing valves with positioners.

• This is time consuming, labor intensive, and requires valves to be removed from the process.
First Generation Digital Positioners

Diagnostics

• The Offline tests (such as the valve signature) that were previously conducted using external devices, were embedded into digital valve controllers to eliminate the need for these external systems.

• Many manufacturers provide these diagnostics. Results must be available from when the valve is new to use for comparison and often require specialized expertise to interpret.
First Generation Digital Positioners

Offline Valve Signature

- The main limitation is that these tests can only be run when the process is inactive, and this of course means the diagnostic information is never up to date and thus it is not possible to make maintenance personnel aware of the control valves’ current condition.

- These obviously do not fulfill the needs of continuous condition monitoring for predictive maintenance planning, nor can they help if troubleshooting is needed while the process is running.
Next Generation Digital Positioners

Online Valve Diagnostics

- The second generation of valve diagnostics included run time data for the valve assembly. State of the art valve controllers enabled sufficient run time diagnostics data to support a predictive maintenance strategy.
- This data included, up to 20, runtime measurements of factors such as valve assembly friction and deviations.
- Trending of historical data over the life time of the valve assembly is helpful for determining how possible problems have developed, and how they may develop into the future.
Next Generation Digital Positioners

Simplifying Diagnostics Analysis

• There is now a focus on helping operators quickly determine the status of valve assemblies with a clear summary of the valve assembly’s health, without requiring in-depth training on valve diagnostics.

• Graphical displays are used to simplify the users experience and give them all of the key information they need on a single page
  - A summary of the health of the valve assembly components, i.e. valve, actuator and positioner, as well as control performance and the environment.
  - Key measurement values such as the supply and actuator pressure difference is displayed, as well as the target versus valve position
  - Recommended Actions provide clarity to make correct maintenance decisions with little time/effort
From Offline Signatures to Online Diagnostics

- No extra work during start-up or shut down
- No extra costs for diagnostics features
- Know your valve condition in the past, present and in the future. Correct focus for the shut down maintenance
  - Valve performance is assessed during run-time
  - Smart devices measure and store the diagnostic data by itself
  - Best possible resolution and accuracy of information
Smart Positioners Diagnostic Types

• Smart Positioners have varying capabilities:
  
  - Smart Positioners with Embedded vs. system based analysis
    • With Embedded diagnostics the positioner stores all of the key information into its own memory so the asset management system simply needs to display it.
    • System based diagnostics require a full asset management system which polls the devices for data and the system performs analysis on the data.
  
  - Smart positioners without pressure sensors
    • Deviation and time based diagnostics
    • No pressure knowledge so changes in valve friction cannot be accurately measured. Other issues like supply pressure cannot be detected.
  
  - Smart Positioners with pressure sensors
    • Deviation, time based, and pressure (friction) based diagnostics.
Example of how Diagnostics are used…

Actuator Diaphragm Leak

Actuator membrane has failed, leakage increasing!

• Problem
  - Diaphragm Leak is developing in the actuator while the process is running.
  - Positioner compensates for the small leak by sending more air to the actuator.

• Control System Diagnostics
  - Once the actuator leak becomes more than the positioner can compensate for the process will be affected and process alarms will be activated.
Example of how Diagnostics are used…

Actuator Diaphragm Leak

• Different smart positioner diagnostic levels:
  - 1st Generation Offline Testing
    • Once actuator leak becomes more than the positioner can compensate for a deviation alarm will be activated since it can no longer follow the set point.
  - 2nd Generation Online Diagnostics
    • Trending clearly shows the change in pneumatics output to compensate for the leak. Some knowledge is required to know what this diagnostic means and what actions need to be taken.

![Graph showing Spool Valve Position over time](image)
Example of how Diagnostics are used…

Actuator Diaphragm Leak

• Different smart positioner diagnostic levels continued:
  - 3rd Generation Simplified Online Diagnostics
    • Diagnostics are broken down into key indexes and clearly show a problem developing with the actuator. A clear description is given describing the problem and recommended actions.

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**Performance View**

- Supply Pressure
- Actuator Pressure Difference
- Target Position
- Valve Position

**Performance Report**

- Supply Pressure: 60.0 psi, Valve Position: 51.5 %
- Actuator Pressure Difference: 38.0 psi, Target Position: 51.3 %
- Calculated Deviation: 0.2 %

Actuator Possible pneumatic leakage.

Check the 'Spool Valve Position' trend. Pneumatic leakage can be seen when the trend level has increased or decreased.
Summary

Advantages / Disadvantages

• Analog Positioner Advantages over Digital
  - Easy to understand / simple design.
  - Lower initial purchase price

• Digital Positioner Advantages over Analog
  - Simplified calibration
  - Improved valve response / accuracy
  - Ability to linearize installed flow characteristics
  - Lower total cost of ownership due to faster startup, ease of diagnosing problems, lower air consumption…
  - Can notify of problems with the positioner, environment (i.e. supply pressure / temperature), and the valve/actuator (friction / air leaks)
  - Can collect historical data over the life of the valve for predictive maintenance
Thank You

Questions, Comments