

Unlocking Reliability:
Continuous Monitoring &
Digital Twin for
Control Valves

Breakthrough
engineering for
a better world

Unlocking Reliability: Continuous Monitoring & Digital Twin for Control Valves

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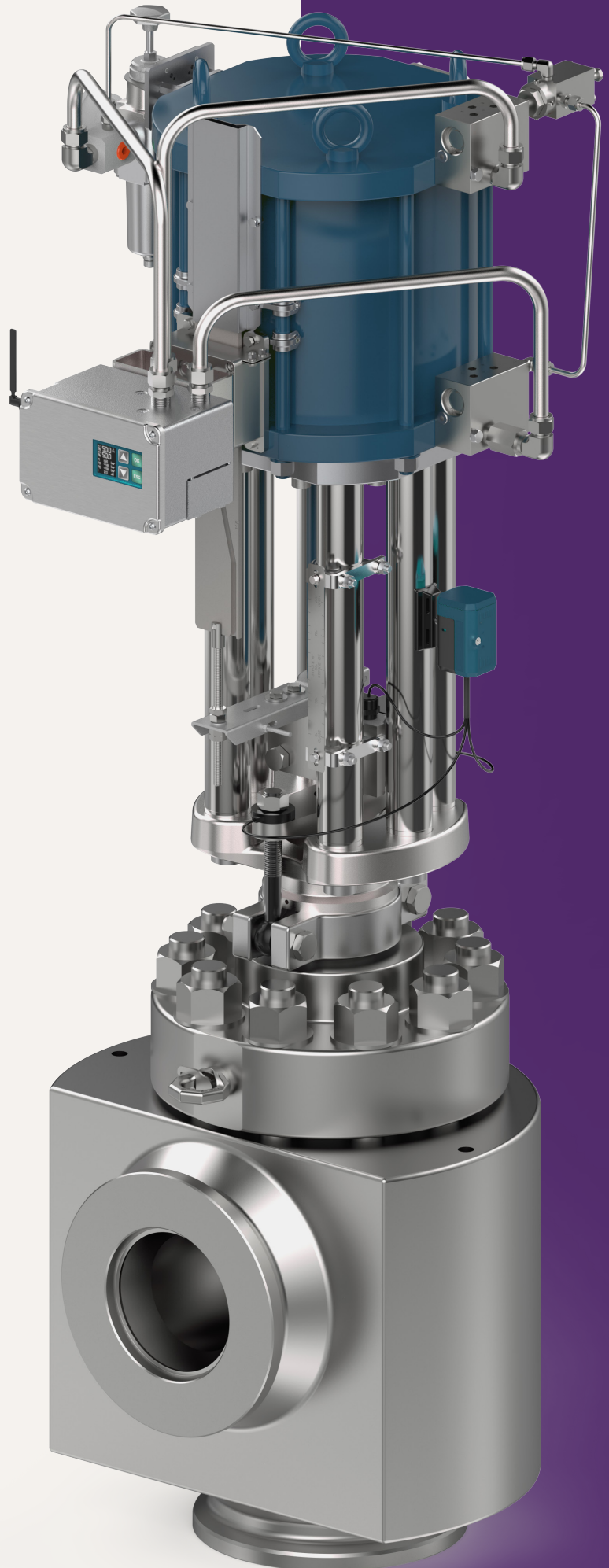
Executive Summary

With control valves responsible for up to 30% of plant failures, we understand how costly unplanned downtime in oil and gas facilities is for you. These failures disrupt your production, resulting in millions in lost revenue per incident, and pose serious safety, compliance, and equipment risks to your people. Traditional monitoring methods, such as HART diagnostics, offer only periodic checks, exposing operators to unforeseen breakdowns.

Our Smart High Performance (SHP) Positioner directly addresses this challenge for you. By combining continuous data monitoring with digital twin technology, the SHP enables plant operators to:

- Predict and prevent failures through real-time health insights.
- Accelerate recovery with emergency hot-swap replacement and with no recalibration needed.
- Streamline commissioning and maintenance via smart configuration and digital inventory.
- Maximise uptime and safety with proactive, data-driven decision-making.

With our SHP technology, your plant can move from reactive troubleshooting to predictive reliability management, reducing your downtime, maintenance costs, and risk exposure. The result: safer operations, optimised production, and a clear path to higher profitability.



Introduction

Control valves contribute to 20–30% of total plant failures, making them a leading cause of reliability issues*

Maintaining plant reliability is essential for smooth operations in the ever-evolving oil and gas sector. It significantly influences profitability, safety, and regulatory adherence. Control valves are vital in securing this reliability since their efficiency directly affects process stability, equipment longevity, and overall operational effectiveness.

The data below highlights equipment that can contribute to plant failures over time. It has been taken from industry benchmarks, reliability studies, and failure mode analyses from a range of sources, including:

ISA (International Society of Automation) – Reports on control valve reliability and failure rates.

API (American Petroleum Institute) Standards – Specifically API 570 (Piping Inspection), API 621 (Reconditioning of Control Valves), and API RP 556 (Instrumentation and Control).

RCM (Reliability-Centred Maintenance) Studies – Published by organisations like the Society for Maintenance & Reliability Professionals (SMRP).

| Equipment | Contribution to plant failures (%) | Common failure causes |
|---|------------------------------------|---|
| Control Valves | 20–30% | Sticking, leakage, slow response, cavitation, actuator failure, positioner issues |
| Pumps | 15–25% | Seal leaks, impeller wear, vibration, misalignment |
| Compressors | 10–20% | Surge, bearing failure, lubrication issues |
| Heat Exchangers | 10–15% | Fouling, leaks, corrosion |
| Turbines | 5–10% | Blade erosion, vibration, thermal stress |
| Piping & Valves (other than control valves) | 10–15% | Corrosion, fatigue, leaks, pressure surges |
| Electrical & Instrumentation | 5–10% | Sensor failure, wiring issues, power supply failures |

The financial impact of unplanned refinery shutdowns resulting from control valve failure



Direct production losses

A medium to large refinery processes **200,000–500,000** barrels of crude oil per day (bpd).

If an unplanned shutdown lasts 12 to 24 hours, lost production can be:
200,000 bpd refinery ☹️
8.3k–16.6k barrels lost per hour.
500,000 bpd refinery ☹️
20.8k–41.6k barrels lost per hour.

Assuming a refined product value of \$80–\$100 per barrel, revenue loss per hour:
200,000 bpd refinery:
\$660k–\$1.6M per hour
500,000 bpd refinery:
\$1.6M–\$4.1M per hour

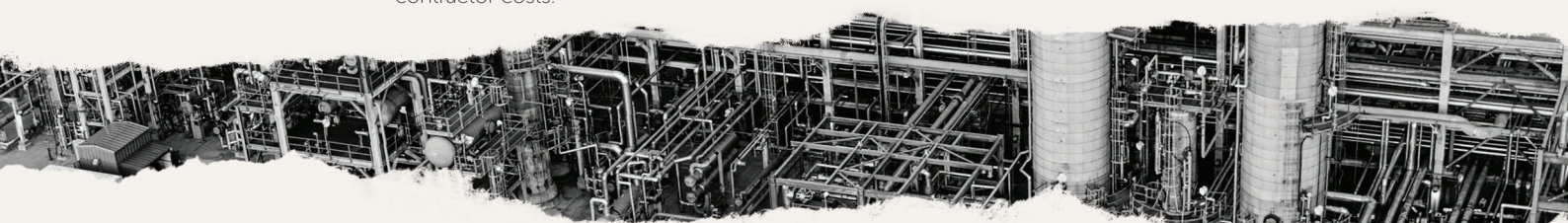


Restart and maintenance costs

Control valve failures may require emergency maintenance, leading to extra labour, spare parts, and contractor costs.

Depending on severity, typical maintenance costs for critical valve repairs can range from \$50,000 to \$500,000.

If damage extends to other equipment (pumps, compressors, heat exchangers), costs can escalate to millions.



Equipment damage and safety risks

Severe failures (e.g., valve sticking in a high-pressure system) can cause overpressure events, pipe ruptures, or fires, increasing repair costs and regulatory fines.

Safety incidents can lead to legal liabilities and insurance claims in the millions.



Problem statement

Control valves are critical components whose failure can cause significant unplanned downtime, safety risks, and financial losses. While valve performance and behaviour are crucial for reliable operation, they are often treated separately.

However, traditional HART diagnostic techniques, such as online and offline diagnostics, are limited to periodic checks and do not provide continuous insight.

These methods alone cannot guarantee full-time visibility or offer 100% assurance in predicting impending failures. So, relying solely on HART diagnostics leaves a gap in proactive maintenance and real-time reliability assurance, highlighting the need for a more comprehensive and continuous monitoring solution.

Control Valve Performance and Behaviour

How do the performance and behaviour of control valves affect oil and gas plants?

Control valve performance

Control valve performance refers to how well a valve achieves its intended function: regulating fluid flow in a system. Valve performance is measured using parameters and attributes that directly impact its efficiency, reliability, and suitability for a given application.

Control valve behaviour

Control valve behaviour refers to how valves respond to variations in the operating environment, control signals, and system dynamics. It encompasses the valve's dynamic characteristics and ability to react under different operating conditions.

| Aspect | Performance | Behaviour |
|--------------|---|---|
| Definition | Quantifiable metrics of how well the valve regulates flow (e.g., Cv, accuracy, response time) | Sticking, leakage, slow response, cavitation, actuator failure, positioner issues |
| Focus | Efficiency, accuracy, capacity, and range of control | Seal leaks, impeller wear, vibration, misalignment |
| Measurement | Directly measured through testing and calibration (flow tests, pressure drop analysis, etc.) | Surge, bearing failure, lubrication issues |
| Importance | Ensures the valve meets specific design and operational criteria | Fouling, leaks, corrosion |
| Implications | Impacts energy efficiency, process control precision, and safety | Impacts process stability, valve longevity, and overall system performance |

Why do both aspects matter?

- **Optimised system performance:**

Both performance and behaviour must be aligned to ensure the control valve functions optimally. A valve with excellent performance metrics may still cause system issues if its behaviour leads to instability or oscillation.

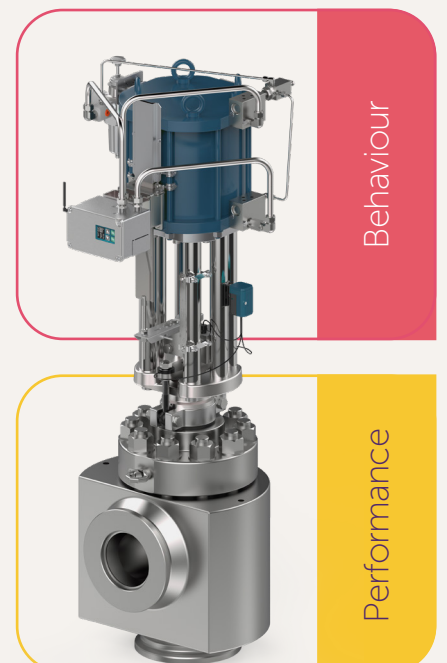
- **Application suitability:** Different applications require different characteristics. For example, a valve with high precision and quick response time may be necessary for a critical process, while stability and minimal noise may be more important in other settings.

- **Maintenance and reliability:**

Understanding both aspects helps select the correct valve for the application, which can reduce wear and tear, minimise maintenance needs, and extend the valve's lifespan.

- **True predictive nature:**

Behaviour problems can be an early warning sign that the valve will have performance concerns later.



Monitoring the health of control valves: HART Protocol

Two primary approaches to monitoring control valves' health are real-time data monitoring and diagnostic techniques. Each plays a crucial role in detecting issues and ensuring optimal valve performance. However, they differ in their approach to problem detection.

Real-time data monitoring

Continuous real-time data monitoring focuses on collecting and analysing key operational parameters of control valves over time. This method aims to track performance trends and flag deviations that could indicate valve issues. Below are the key aspects of this approach.

The sensors continuously monitor parameters such as:

- Valve position
- Actuator performance (air supply, pressure)
- Valve stem travel and response time
- Control signals (input/output)
- Temperature and pressure of the fluid
- Flow rate and leakage

By smart positioner
By external sensors with DCS

Diagnostic techniques

These techniques use offline and online diagnostic methods to identify specific valve problems or failure modes and normal and abnormal patterns in valve data.

Online diagnostics

The online method involves scheduled or on-the-spot monitoring while the valve responds to the DCS signal as a normal operation. Key aspects include:

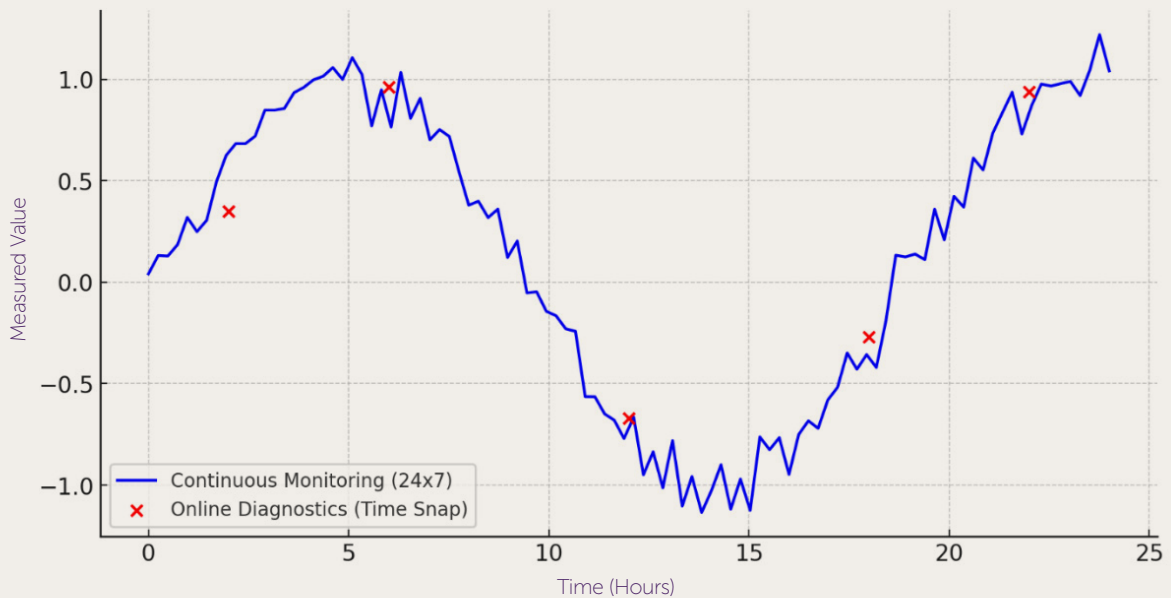
- Supply pressure
- Online friction
- Active alerts and deviations
- Positioner status alerts (HART CMD48 – NE107)

Offline diagnostics

The offline method involves conducting tests that require moving the valve while it is connected to power, but it does not respond to any control signal. Key tests include:

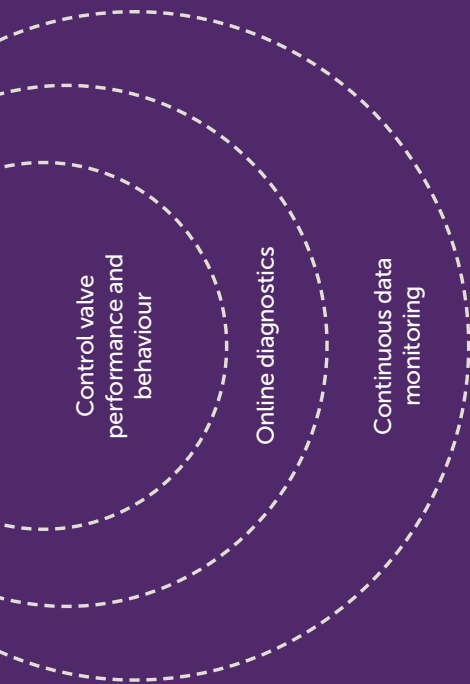
- Valve signature analysis
- Step response testing
- Hysteresis checks
- Stroke testing

Comparison of Continuous Monitoring vs Online Diagnostics



The Theory of Failure

Online diagnostics can collect time intervals for valve performance and behaviours. However, continuous data monitoring provides all-time coverage for collecting valve performance and behaviours.



Each control valve will fail or cause a plant trip, thereby exhibiting abnormal behaviour or poor performance. Predictive maintenance helps identify such issues before they occur. Correct analysis of the control valve's collected aberrant behaviour will keep the plant ready with the correct tools and minimal downtime.

Solution: IMI's Smart High-Performance (SHP) Positioner



What is the SHP?

The Smart High-Performance Positioner is our newest final control smart positioner with a data monitoring system. Data monitoring is an inbuilt function that always works without a human interface. The data is secure, and turning it off or deleting any recorded event is prohibited.

What are the benefits of the SHP?

The SHP can capture up to 200 events, with high data resolution on when they happened, how long they took, what the event was, and the detailed source. The data monitoring covers 21 codes that extend to the valve's performance, behaviour, and configuration history.

Event Codes

The table below retrieves all the events

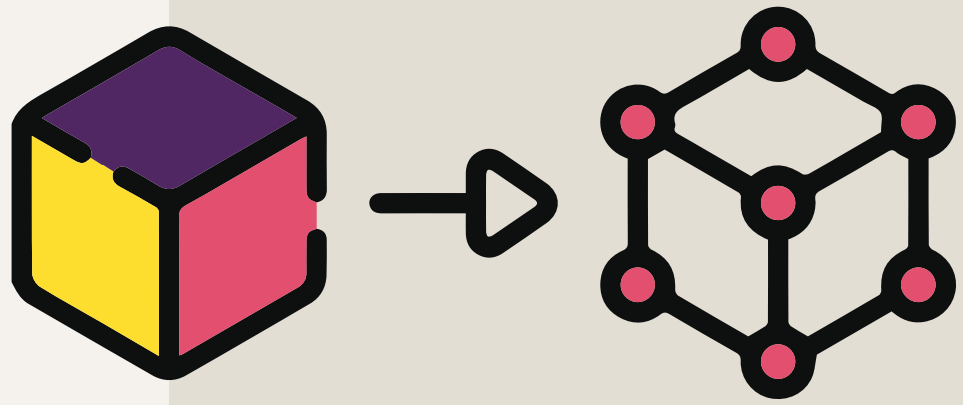
| |
|--------------------------------------|
| Position out of Range |
| Position Physical Limits [ON] |
| PB out of Range |
| PA out of Range |
| PI out of Range |
| PI < Min. Pressure |
| Position Control Failure |
| Power |
| Input Current Low |
| Position Sensor Fault |
| Factory Configuration Reset |
| Factory Configuration Recovery Filed |
| User Configuration Reset |
| User Configuration Recovery Filed |
| Position Sensor Magnetic Field Low |
| I-P Module Disconnected |
| Trial License |
| PST Started |
| PST Finished OK |
| PST Finished KO |
| PST Aborted |

| EVENTS & COUNTERS | | | |
|--------------------------|----------|------------|----------|
| Event | On (m) | Date | Time |
| PI < min. pressure [OFF] | 00137479 | 2022-09-28 | 05:46:27 |
| PI < min. pressure [ON] | 00137026 | 2022-09-27 | 22:12:00 |
| PI < min. pressure [OFF] | 00136038 | 2022-09-27 | 05:46:29 |
| PI < min. pressure [ON] | 00135592 | 2022-09-26 | 22:20:00 |
| PI < min. pressure [OFF] | 00134558 | 2022-09-26 | 05:45:30 |
| PI < min. pressure [ON] | 00132301 | 2022-09-24 | 15:28:53 |
| PI < min. pressure [OFF] | 00131718 | 2022-09-24 | 05:45:17 |
| PI < min. pressure [ON] | 00131281 | 2022-09-23 | 22:28:56 |
| PI < min. pressure [OFF] | 00130278 | 2022-09-23 | 05:45:18 |
| PI < min. pressure [ON] | 00129836 | 2022-09-22 | 22:23:50 |
| PI < min. pressure [OFF] | 00129377 | 2022-09-22 | 14:44:56 |
| PI < min. pressure [ON] | 00129376 | 2022-09-22 | 14:43:50 |
| PI < min. pressure [OFF] | 00129375 | 2022-09-22 | 14:42:33 |
| PI < min. pressure [ON] | 00129217 | 2022-09-22 | 12:04:39 |
| PI < min. pressure [OFF] | 00128938 | 2022-09-22 | 05:45:56 |
| PI < min. pressure [ON] | 00128374 | 2022-09-21 | 22:01:06 |
| PI < min. pressure [OFF] | 00127358 | 2022-09-21 | 05:45:49 |
| PI < min. pressure [ON] | 00126945 | 2022-09-20 | 22:12:44 |

Read Events Stop Reading

The SHP's memory is embedded with a non-human interface, a 24/7 working event log recording with the exact date and times of events. Each of these events will be recorded on the dashboard.

The SHP Digital twin



A digital twin is a virtual model representing control valve configurations, correct tuning levels and calibration data. Digital twin technology transforms plant reliability, efficiency, and operational decision-making. The smart positioner must be able to work with digital twin data, including calibration, without having to be recalibrated again.

How does a digital twin improve plant reliability?

Digital twin and data-driven insights

By integrating digital twin technology, valve performance and calibration, data can be continuously analysed in a virtual environment by:

Proactive maintenance: The digital twin uses a digital copy of parameter and calibration data, FAT or SAT, to simulate and predict future valve issues, allowing maintenance planning based on the actual valve condition.

Enhanced calibration: Real-time calibration of actuators ensures the valve's responsiveness remains precise, avoiding performance drift and improving reliability.



Emergency online replacement [Hot Swap]

If a problematic positioner needs to be replaced online, there is no need to interrupt the process loop or recalibrate. A smooth transition to a new positioner ensures regular operation.



Smart commissioning

The digital twin can validate valve setup during commissioning, ensuring it is configured correctly before starting live operations, with a FAT digital twin copy supplied along with the valves.



Digital inventory

Control valves with similar actuator sizes and stroke. A digital twin of the positioner configuration and calibration allows for easy download and installation of the digital twin without the need for calibration, resulting in minimal downtime.



Digital redundancy

Critical valves maintain the digital twin of positioner configuration and calibration data ready for the second positioner. If the primary positioner fails, the redundant positioner, equipped with ready digital twin data, will take over functioning.

The digital twin of the malfunctioning positioner can be transferred to a new shelf positioner in the inventory.

Uploading the digital twin copy can take a few minutes using the IMI free remote software.

There is no requirement to trip the plant or disturb the process loop. To replace the physical positioner, the valve can be fixed at a certain position using either the handwheel or the spool.

After changing it, no action is required; the new positioner will respond immediately and without the need for calibration.



Key recommendations

- Choosing the right accessories and the ability to reduce the number of accessories between the smart positioner and actuator will lead to precise diagnostics results and real data monitoring.
- A high Cv smart positioner will be the standard selection for actuators installed on large valves where two standard volume boosters can be replaced.
- A smart positioner will have the digital twin technology for configuration and calibration.
- By combining continuous monitoring and diagnostic techniques, you will reach predictive maintenance strategies to anticipate potential failures and proactively schedule maintenance activities.
- Real control valve health monitoring

Conclusion

Control valves are pivotal to plant reliability. Plants can reduce downtime, ensure safety, and optimise operational performance by maintaining proper control, performing regular monitoring, and leveraging digital twins for predictive maintenance.

Reliable control valves lead to consistent process stability, cost savings, and longer equipment lifespans.

Process Automation

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