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Valves and Actuators: Maintaining the Foundation of High Performance Buildings

by Mark Sarna and Dave Savage

Executive summary

Control valves and actuators are the unsung and unseen heroes of building management systems. They control a large amount of the 35% of energy used in a building's HVAC system. Yet they are routinely ignored when it comes to system maintenance. This paper explains how control loop and valve service inspection can save time and money. Proactive, predictive valve maintenance programs are also discussed.

Introduction

Building owners invest significant resources in environmental and building control systems. These systems can be costly to operate, yet essential for occupant comfort, productivity and safety. Of all the devices and systems inside a building that control the environment and manage energy use, valves and actuators are most frequently overlooked despite the fact that they form the foundation for an effective Building Management System, or BMS.

"HVAC equipment including valves, actuators and sensors can account for approximately 35% of energy use in commercial buildings."

HVAC equipment including valves, actuators and sensors can account for approximately 35% of energy use in commercial buildings.[1] Efficient, smart buildings manage those costs with reliable HVAC control devices that help regulate and decrease a facility's energy use. These devices provide early warning of potential problems and dangerous system conditions. Valves and actuators play an important role in HVAC control for a variety of applications; including fan coil units (FCU's), air handling units (AHU's), chillers, boilers, and variable air volume reheating among others. These applications are found in a wide range of market segments; such as healthcare, data centers, commercial buildings, and education.

While these critical control devices can operate for years without a problem, when something does go wrong it often goes undetected. Valves and actuators are often not a specific focus in most service contracts, and are simply considered part of the overall BMS. Despite the importance and expense of maintaining building efficiency, most building owners/operators – some 55% in the United States[2] - rely on reactive maintenance strategies. This means they wait until equipment, for example critical control devices, falter or fail completely before initiating corrective action. By acting only when a failure occurs, building stakeholders risk that repair costs will be at a maximum and that interruptions to service will occur while repairs are being made. This impacts not only the cost and performance of the HVAC system, but also the entire BMS.

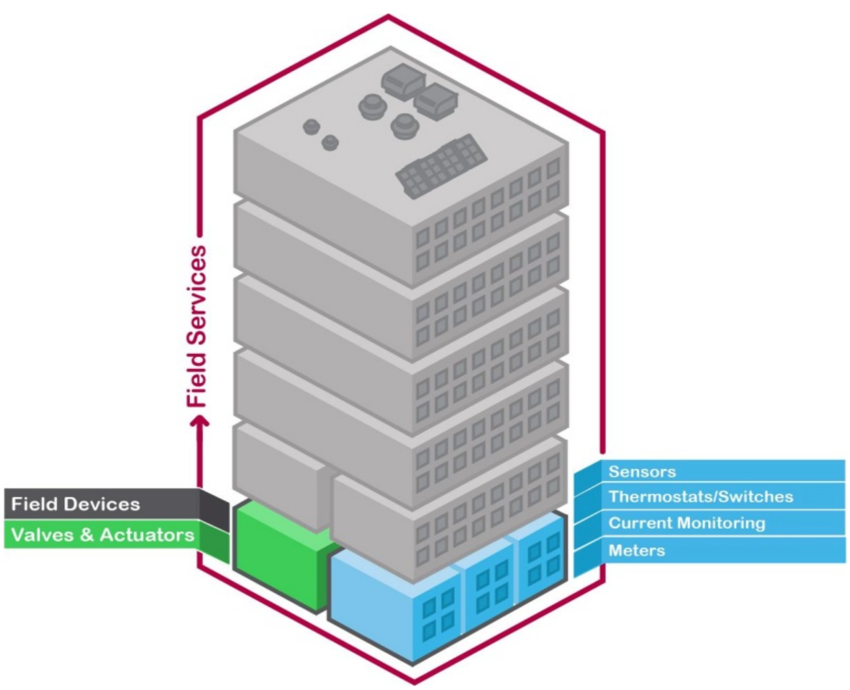


Figure 1

Valves and actuators sit at the core of a building's physical infrastructure

[1] http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=3.1.4

[2] http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-19634.pdf

In these instances predictive maintenance contracts have the potential to deliver significant energy savings and improved building performance and comfort. Using analytics to leverage the data generated by modern systems and devices that make up the building infrastructure network is the most efficient approach. The data provides accurate, timely and actionable information that can be leveraged to refine service programs and achieve optimal building performance and cost-effectiveness. Building owners and operators are then in a position to make data-driven decisions based on the impact of maintenance on building efficiency and performance.

This paper discusses the nature and cost of poor valve/actuator performance, and prescribes a proactive, predictive valve maintenance approach.

The significance of valves and actuators

Valves and actuators seem like simple devices, but their sheer number can make maintenance a challenge. A large commercial facility could have thousands of valves and actuators throughout the building located in individual spaces, AHUs and the central plant. Furthermore, they perform critical functions. For example, the fluid control valve regulates the level of energy output from a heating or cooling coil, which in turn has a large impact on comfort and energy costs throughout a space or building.

Even newer buildings can experience hidden valve problems. Some typical problems include:

- Improper installation, selection or sizing
- Linkages become disconnected
- Reset activates a manual override
- Debris during the flushing cycle can foul internal workings
- Chemicals during the flushing cycle can damage seals

Despite their importance, for most facility managers, valves are not top of mind. Most often, electrical components such as pumps and fans, where it's easy to see power usage and cost in KW/h, present a higher priority. However, valves and actuators are often the root cause of serious problems such as poor equipment performance, unproductive maintenance calls, and unexplained rising energy use. This, in turn, leads to the following issues:

- Increased costs due to unplanned equipment downtime
- Increased labor costs, especially when overtime is needed
- Costs involved with repair or replacement of equipment
- Possible secondary equipment or process damage from equipment failure
- Inefficient use of staff resources

HVAC systems consume about 35% of the energy in most commercial buildings with valves and actuators responsible for a significant amount of that environmental control. Bottom line: When the valves aren't healthy, the building isn't healthy. They enable efficiency and contribute to the overall value of the BMS. If measurement of control at the field device level is not efficient, the BMS is not performing at an optimal level and services are relegated to "firefighting mode".

Case Study: The ROI of healthy valves

Busey Bank in Champaign, Illinois, recommissioned its 100-year-old office building to improve energy efficiency and occupant comfort.

A key part of the project was a network of Schneider Electric zone valves installed throughout the building to precisely regulate steam flowing through the 5.08 cm steam distribution piping running to each of 16 different zones. Other systems were also upgraded, including pumps, fans, sensors, and smart thermostats. The network is linked to a BMS to monitor and control systems.

The results: Annual kWh usage was reduced from 1.8 million to 1.2 million, a 30% savings, with 100% ROI in project costs in just 18 months. An ongoing service plan provided by Alpha Controls, the Schneider Electric partner that installed the systems, ensures continued valve performance and energy efficiency.

Common valve problems

The purpose of a building management system is to control and adjust the environmental systems to achieve a desired temperature while minimizing energy consumption. Variables such as changing occupancy, load on the building system, and seasonal changes require that valves adjust appropriately and accurately under varying conditions. Valves are constantly working and are subject to wear, as well as to damage from chemicals or debris.

The damage that can occur falls into two general categories: physical problems and system problems. Either can result in wasted energy, unnecessary equipment wear, and poor occupant comfort.

Physical problems

Typical physical problems include leakage via the valve seat (internal) or valve stem (external), worn actuator linkage, and noise in the piping system. Sometimes actuators are manually positioned (in which case its position is lost if there is no feedback or recalibration). Other problems include:

- Damage to valve internals/seals from debris in the water, excessive chemicals, or foreign matter introduced through an open system.
- A leaking or overridden valve that needs the associated opposite valve to compensate. The opposing coil consumes extra energy by compensating for the load. This is very costly especially in buildings with large cooling loads. This situation may not be detected as the desired temperature is achieved, but at the cost of greater energy consumption.
- Control loop hunting, in which a heating and cooling valves operate in a sequenced cycle from closed to 100% open. When an overshoot of the set point occurs, the control loop then reacts by closing both valves in sequence and then starts to open them to 100%, and then back to the closed position. This scenario is often associated with incorrect PID control loop parameters or seasonal performance variation and is extremely energy inefficient.

Case Study: Fixing valves, saving money

A 41,806 square meter research lab in the greater Boston area used building analytics to identify and repair faulty valves. Results included:

• A leaking cooling valve in an air handler was causing simultaneous heating and cooling of air supplied to the building during heating season. Replacing the unit has saved more than €57, 304.77 per year.

• A preheating coil valve was put into manual override during the summer months. Once heating season began, the overridden valve began to cause simultaneous heating and cooling. Correcting the valve controls as has saved €128,715.07 per year.

• Nearly 200 of the building's terminal unit reheat valves were found to be leaking, caused by unfiltered hot water during the building startup. Replacing the faulty valves and actuators has saved €72,452.40 per year.

Control system problems

Control loop stability is an essential part of energy efficiency. The BMS utilizes proportional-integral-derivative (PID) loops and their associated algorithms connected to sensors to respond to conditions with incremental adjustments to actuators, valves, fans and pumps. Problems in these systems can result in poor valve performance. Common control system problems include:

- Noise in the control signal—interference or poor wiring disrupts the signal, impairing communication between valves and other systems.
- Incorrect valve sizing and sensor-to-room pairing, or sensors out of calibration.
- Too much pressure at the valve inlet—this can cause the system to be noisy or the valves not to close off properly; the pump control system is unable to regulate pump head pressure affecting proper valves operation and ultimately energy efficiency.
- Improper response to temperature changes—this will manifest itself through seasonal outdoor temperature changes (loads), equipment set point temperatures, or how the system is tuned to respond.

All of these are design or system variables or conditions that the BMS has some level of control over. Control loop hunting, referred to above, can be difficult to detect and occurs when the valves/actuators are maintaining temperatures within tight parameters (e.g. +/- 0.5 °C), but the control loop is unnecessarily cycling between heating to cooling every few minutes. Seasonal tuning can ensure all loops are stable by monitoring the control temperatures and valve positions over a time period, either on site next to the AHU or from the BMS terminal.

Valve and actuator inspections

To avoid the problems described above, valve and actuator inspection should be incorporated as part of a regular proactive, predictive maintenance strategy.

Although reactive maintenance is the most popular approach,[3] the highest-performing facilities overwhelmingly use preventative maintenance and rarely utilize reactive maintenance.

According to U.S. government figures,[4] comprehensive operations and maintenance programs, based on proactive, predictive maintenance combined with analytics, can save up to 20% per year on maintenance and energy costs, while increasing the projected lifetime of the building by several years. The key to predictive maintenance is that equipment and system conditions determine what maintenance is performed, as opposed to a preset schedule. This means that repairs are performed at the ideal time, resources are not wasted on unnecessary work and equipment (including valves and actuators) is maintained at its highest performance levels.

"Proactive, predictive maintenance and analytics can save up to 20% per year on maintenance and energy costs."

Predictive maintenance can leverage automated sensors and expert knowledge to help prioritize overall system and valve and actuator maintenance. Taking this concept a step further, integrating all of the data coming from the BMS and connected devices with advanced analytics capabilities creates a true "smart service plan" approach. The plan provides accurate information about facility issues and then ranks them by how they impact the business in different areas such as energy cost, comfort, and maintenance urgency.

Since most buildings today are "smart" to some degree — meaning they have some type of BMS capability — implementing a "smart" service plan is a natural next step. Such a plan allows the facility to leverage the data that the BMS collects and put it to use in new ways to reduce energy use and overall costs.

This overall system maintenance approach also ensures that control valves are operating as designed and that control loops are tuned and optimized for energy efficiency. If using an outside company to service equipment, valve inspection should be part of the service agreement.

More on the value of a predictive maintenance strategy for building operations, including regular valve and actuator inspections, can be found in the Schneider Electric white paper, "Predictive Maintenance Strategy for Building Operations: A Better Approach."

Inspection best practices

Inspections can be performed in various ways, depending on resources and building type:

- Simple visual inspection of the control valve and actuator can be an effective way to detect obvious mechanical problems. This approach is challenging in a facility with hundreds of valves, but the inspections can be scheduled throughout the year to make them manageable. Visual inspection may be especially difficult in some office spaces or hotel rooms where the control valve

[3] http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-19634.pdf

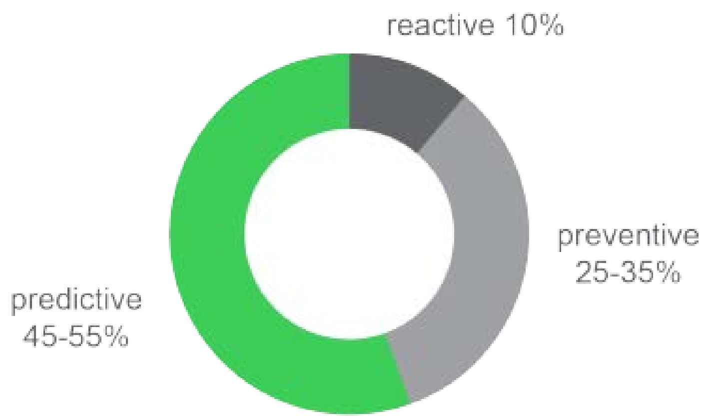
[4] Ibid.

is not readily visible and may require a panel or ceiling tile be removed in order to access.

- Visually checking trend logs in a BMS terminal can help to detect anomalies in equipment performance, to be followed up with physical inspection where indicated.
- The above inspection techniques can be augmented by using building analytics tools, which offer a precise methodology for monitoring energy waste through control valves. Analytics can identify possible valve problems that would otherwise be difficult to detect.

Figure 2

Types of maintenance programs used in top-performing facilities



Case Study: Protecting national treasures

To protect its priceless artifacts, the Lincoln Presidential Library and Museum in Springfield, Illinois must maintain a constant 20° C and 45% relative humidity level year-round, around the clock, with a deviation of just +/- 1%.

This requires valves and actuators to perform with extraordinary precision year after year, opening and closing repeatedly throughout the day in response to constantly changing heat loads. Dozens of Schneider Electric valves, damper actuators, and S-Link sensors provided the level of control needed, at an affordable cost. Performance is maintained by a regular service plan.

The result: Lincoln Library and Museum is able to keep its priceless artifacts and documents safe, and visitors comfortable.

In all cases, when an inspection is performed, it is good practice to include photographs of system conditions to support the engineer's report which can be referred to on subsequent inspections.

The following steps are recommended as part of an effective valve inspection program:

Checklist for valve inspection

- ☐ Test for control loop stability by monitoring the control temperatures and valve positions over time either at the plant room or from the higher level BMS to which the devices are connected.
- ☐ Create a trend graph with valve/damper actuator positions, available temperature (supply, discharge, and space) and observe that the heating and cooling systems are functioning as designed during normal operation. If irregularity is observed, such as hunting or temperature response, then tune the control loop accordingly.
- ☐ Visually check the valve for leakage.
- ☐ Close the drive valve and allow time for the downstream temperature to stabilize. Then check with a temperature probe to establish the valve is shutting off. If there is evidence of let-by then investigate further. (See Appendix for more information)
- ☐ Check for valve stem showing signs of weeping around the gland. If present, replace gland kit or entire valve.
- ☐ Look for signs of galvanic corrosion on valve body and pipe work. This can lead to leaking and requires wire brushing and anti-corrosive paint applied or the connection remade in severe cases.

- ☐ Check valve bonnet for evidence of scoring, likely caused by faulty actuator mounting; tighten accordingly.
- ☐ Check for rattling sounds (preferably use acoustic listening device) which can indicate the plug becoming detached from the stem. If necessary, replace stem and plug assembly or entire valve.

Note that steam valves are especially important to check regularly. They can be more prone to stem failure from internal steam pressure or condensation when open, often resulting in worn plugs or seals or even broken plugs or stems. Special precautions and additional care should be taken when inspecting/working with steam control valves.

Checklist for valve and damper actuator inspection

- ☐ Cycle actuators from open to close by changing the control signal from the BMS; then check the fail return for correct operation.
- ☐ Check that linkages/anti rotation brackets are tight and not showing any signs of wear or play.
- ☐ Check if the actuator has a bent anti-rotation plate and replace if needed. This could be caused by excessive force used on manual override.
- ☐ Check that the actuator linkage or anti-rotation bracket is touching the position indicators. If not, it is likely the actuator has come loose or that sediment is present in the valve stopping it from closing. Check that the actuator has enough force to close.
- ☐ Test the manual override operates correctly and is disengaged at the end of the inspection.
- ☐ Look for fading colors on the position indicator. This can indicate very high ambient/operating temperature leading to premature failure.
- ☐ Listen for excessive noise in the actuator, which could indicate it has been operating for too long. This could be due to a poor control loop or no time-out facility on floating control, either of which could cause potential premature failure.
- ☐ Check to see if the actuator is driving closed and repeatedly trying to close the valve. This indicates the valve has dirt contaminants or simply needs re-calibrating.

Conclusion

Valves and actuators are critical components in a building's environment. They typically control approximately 35% of a building's energy systems.

To ensure control stability and energy-efficient operations, valve inspections should be part of a regular proactive, predictive maintenance strategy that leverages data and analytics to enhance performance. Regular inspection and servicing of valve assemblies will help ensure longer equipment life, lower energy bills, and a more comfortable and safe environment for occupants.

An industry expert, such as Schneider Electric, can provide advice as to how service agreements can cut costs and enhance operational efficiency.

About the authors

Mark Sarna is the Director of Valve and Actuator Engineering and Offer Management within the EcoBuilding division of Schneider Electric. In his current role supporting field devices, he leads offer creation, engineering, product management, and laboratory teams in developing our next-generation valves and actuators. Mark has over 19 years of experience with the engineering, manufacturing, and management of valve and actuator products. He holds a Bachelor of Science in Mechanical Engineering from the Milwaukee School of Engineering.

Dave Savage is a Senior Director of Field Services Business Development within the EcoBuilding division of Schneider Electric; he supports the deployment of advanced service solutions for energy efficient, comfortable, and reliable facilities. Dave has over 37 years of experience with Schneider-Electric in the building controls industry, starting with the first generation of computer-based building energy management. He studied Building Services Design at Newcastle College of Arts and Technology and has experience spanning systems design, site project management, solution sales, product development, and marketing.

Appendix:

Many methods for checking valve leakage have been established. Here is one example of how to check for valve leakage:

1. Manually override the automatic control signal via the BMS so that the control valve is electronically closed.
2. Close the coil isolation valve(s) to stop flow thru the coil and allow time for the coil temperature to stabilize.
3. Check with a temperature probe the on-coil and off-coil temperatures to establish that the temperature across the coil has stabilized.
4. Open the coil isolation valve(s) and recheck the on/off coil temperatures if they remain the same then you can consider the valve stroke and seat to be in serviceable condition.
5. Reset the BMS controls back to automatic.

If the off-coil temperature is either higher or lower than the on-coil temperature, depending on whether it is heating or cooling, it would indicate that the valve is either not stroked correctly, the seat is damaged or letting by and will require further investigation.

If it is related to the actuator then recalibrate the valve stroke using the manufacturer's instructions and repeat the above test. If this still fails, check the system pressures to ensure the valve actuator is suitable sized for the application. If this is correct and the valve is still not closing then it will be necessary to repair or replace the valve body.