

Pressure Regulators in Gas-Fired Power Plant Feed Applications



Introduction

Natural gas-fired power plants are an increasingly important source for generating electricity within North America. Large natural gas pressure reduction stations that are equipped with pressure reducing regulators or control valves drive the operation of gas

turbines within these power plants. Understanding the purpose and operation of regulators installed within pressure reduction stations is essential for operators to ensure the reliability, performance, and safety of the station and plant.

Average Age of Electricity Generation Facility by Type
 Source: EIA

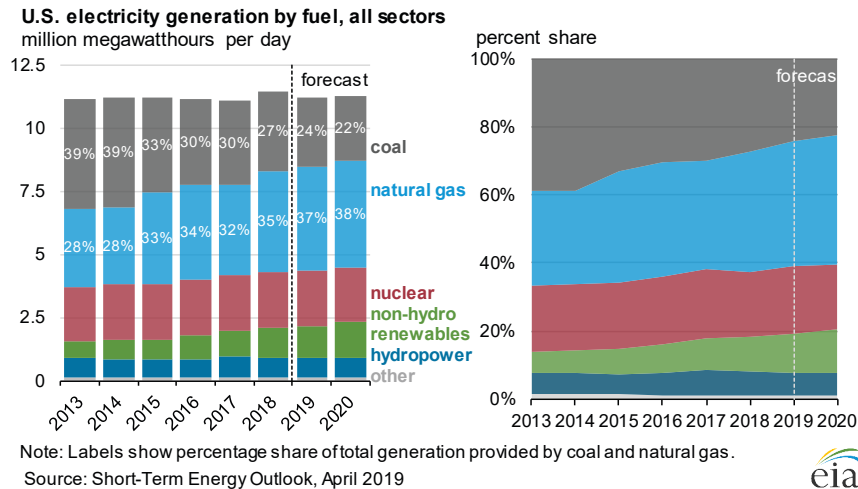
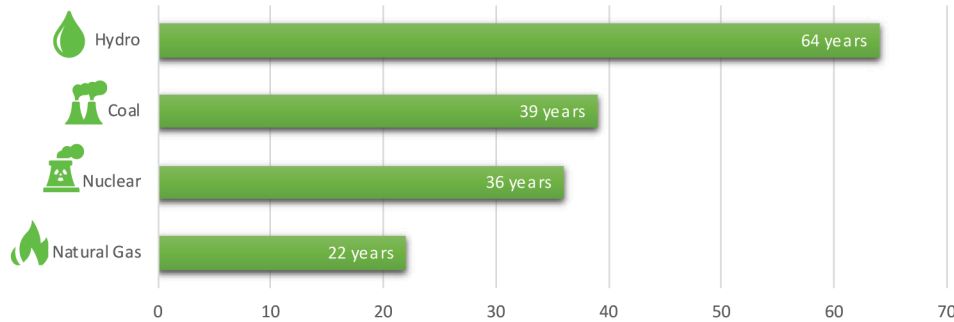


Figure 1. Annual Share of U.S. Electricity Generation by Energy Source

In the United States, coal plants have historically provided the largest share of electricity generation, while nuclear, natural gas, and hydroelectric plants provided supplemental capacity. However, as North America experienced a shale gas boom and governments increased regulations restricting emissions of volatile organic compounds, the largest portion of North American electricity demand shifted to natural gas power plants. According to the Energy Information Administration, clean natural gas surpassed coal as the largest generation type in the United States in 2016; by 2017, natural gas power plants supplied 42% of the electricity capacity and

34% of the generation for the country. Of the natural gas capacity, combined cycle plants comprise 53%, combustion turbine 28%, and steam turbines 17%.

Application Overview

Natural gas-fired power plants typically source gas from a nearby transmission pipeline which can operate at pressures from 200 psig to over 1000 psig. These high pressures, along with high flow required to feed the plant, require the installation of large, pilot-operated pressure reducing regulators, or control valves at the pressure reduction stations that feed the plant.

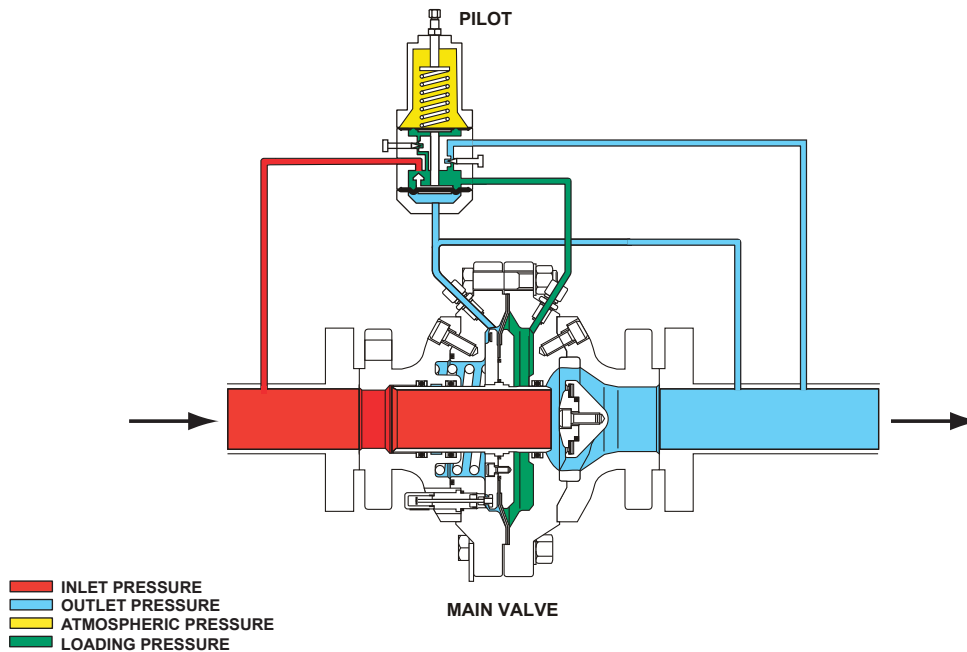


Figure 2. Tartarini Type FL - An Axial Flow, Two-Path Pilot-Operated Natural Gas Regulator

Pilot-operated regulators are self-contained mechanical devices that reduce pressure to a desired set pressure value. These devices are operated by the pressure differential that occurs when there is a change in demand for natural gas downstream. No electrical power or instrument air is needed. Pilot-operated regulators can maintain a set pressure accuracy of 0.5% to 2.5%, even when inlet flow rates and transmission line pressures may vary. This sustains the desired pressure for feeding the power plant’s gas turbines.

Principle of Operation

Pilot-operated regulators have two major components: a pilot valve and a main valve. The pilot is the sensory component and controls the opening and closing of the main valve. The main valve includes an actuator connected to a main valve through which the primary flow passes. Two styles of pilot-operated regulators are available for natural gas applications—1) two-path, loading style and 2) boot, unloading style. Both styles

provide reliable pressure control, but the two-path style best meets the high pressure and large flow requirements of natural gas power plant pressure reduction stations.

In a two-path style regulator, if the downstream pressure decreases because demand for natural gas is increasing, the pilot valve plug moves away from the orifice allowing inlet pressure to fill the loading pressure chamber of the main valve. This increase in loading pressure forces the main valve open, which increases the flow of natural gas downstream, ensuring downstream pressure remains near the setpoint. If downstream pressure increases because demand for natural gas is decreasing, the inverse process will occur. The pilot valve plug moves towards the orifice, restricting flow to the loading pressure chamber and forcing elevated gas pressure within the loading pressure chamber to pass downstream through a fixed restriction. When loading pressure is reduced, the main valve’s spring forces the main plug closed, restricting flow and ensuring downstream pressure remains near the setpoint.

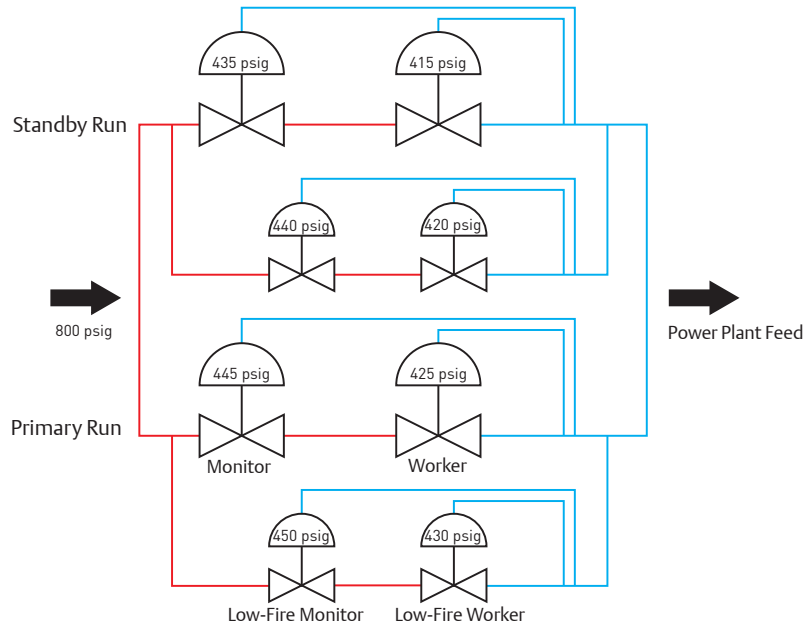


Figure 3. Natural Gas Reducing Station Example

Reliability

The primary goal of a pressure reduction station is to reliably maintain natural gas pressure to the downstream turbines. If natural gas pressure to the turbines drops too low or rises too high, the turbine could be tripped offline. High natural gas pressure can also cause equipment damage, risk the safety of the plant workers, and cause extended downtime.

Pilot-operated pressure reducing regulators installed at power plant reducing stations help ensure reliability by providing a consistent fuel stream for the turbine's combustion process. The regulator responds quickly and accurately to changing downstream pressures because of its direct operating and two path control design. To increase reliability, a station is often constructed in parallel runs to maximize uptime to enable the station to respond to unexpected events or to enable the plant to perform maintenance on the station with the plant operating.

Overpressure and Underpressure Design Considerations

While the mechanical nature of regulators provides long-term reliability, occasionally a failure event at the pressure reduction station can occur, causing overpressure or underpressure to occur downstream. These risks can be mitigated by ensuring the pressure reduction station is designed with underpressure and / or overpressure protections through parallel runs, series regulation, or slam-shut devices. Additionally, instability within stations can be resolved by implementing sizing and installation best-practices.

Underpressure Protection

Pressure reducing regulators are completely mechanical devices that can fail closed, partially closed, or open. Most pilot-operated regulators have main valves with springs that push them closed which makes them more likely to fail in a closed or partially closed position. To ensure that a ruptured diaphragm would not shut down gas feed, many stations have a standby regulator run installed. The setpoint for a standby regulator is staggered from that of the primary regulator, which prevents the standby regulator from operating during normal conditions. By setting the standby run at a slightly lower pressure than the primary run, the standby run will stay closed but prepared to open if the downstream pressure decreases for any reason. Alternatively, the standby run could have an isolation valve keeping it from flowing while the primary run is regulating correctly.

In Figure 4, the regulator on the primary run will cut the pressure from an 800 psig upstream pressure to a 440 psig setpoint. The regulator on the standby run will stay closed unless the downstream pressure decreases to 420 psig at which time it will begin opening to maintain a 420 psig setpoint.

In addition to protection from underpressure events, a duplicate run will enable operators to perform maintenance on the regulating station without shutting the plant down. The natural gas load can be shifted between runs when preventative or corrective maintenance is required, ensuring a constant feed of natural gas is available for the plant.

Overpressure Protection

Piping systems in electrical generation stations are governed by ASME 31.1. One of the many areas covered in the code is the application of overpressure protection, or OPP.

For fuel gas distribution systems, the code allows for an alternate design if a full-relieving capacity safety relief valve creates an undue venting hazard.

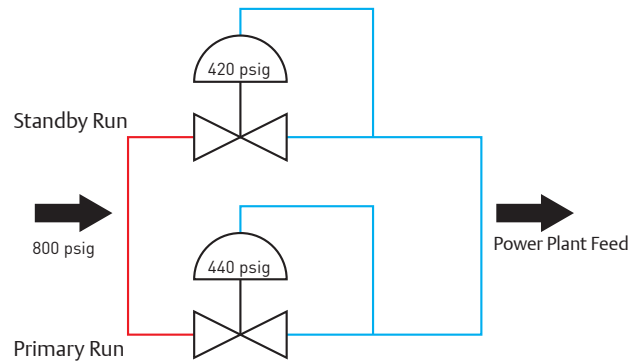
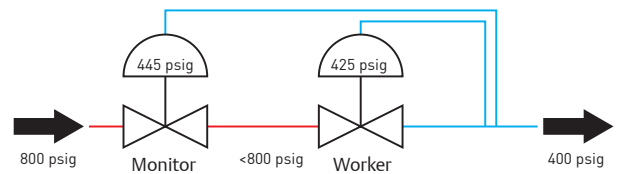


Figure 4. Primary/Standby Setup

Normal conditions:



Conditions after worker failure:

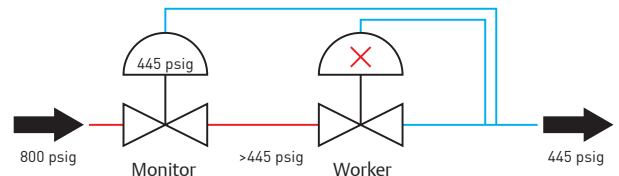


Figure 5. Wide-Open Monitor Setup

The code allows for an alternate method of overpressure protection to be used:

- 1) Tandem Gas Pressure Reducing Valves
- 2) Trip Stop Valves
- 3) Safety Relief Valves

The first method is commonly called a “monitor” setup, where two pressure reducing valves can be used in series. They are redundant, but independent pieces of equipment. When one fails, the other will control pressure and maintain it below the system’s limits. A trip stop valve, or what we call a “slam shut” will rapidly shut prior to the piping’s design pressure from being exceeded, stopping all flow downstream. This is more common in European natural gas systems but is not as widely adopted because it completely interrupts flow. A safety relief device must be adequately sized to prevent pressure limits from being exceeded under worst-case conditions. Although flow should be maintained, lifting will cause loss of product and emissions concerns.

Wide-open monitors are the most common form of overpressure protection in large natural gas distribution applications such as city gate stations, district stations, and large industrial meter sets.

Wide-open monitor configurations place two regulators in series, and both regulators sense downstream pressure via control lines. The monitor regulator’s pressure setpoint is slightly above the active worker regulator’s pressure setpoint, maintaining it open and in a standby mode. If the worker malfunctions and downstream pressure rises, the monitor regulator will take control of the run at its pressure setting.

The monitor regulator can be either the upstream or downstream regulator, but its external registration must sense downstream of the worker’s external registration.

Maintaining Stable Performance

Many regulating stations must accommodate widely deviating maximum and minimum flow requirements. It is usually suboptimal to task a single pressure regulator with managing normal loads, along with

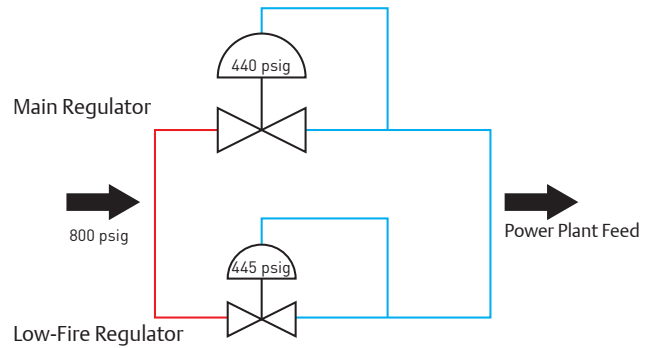


Figure 6. Low-Fire Setup

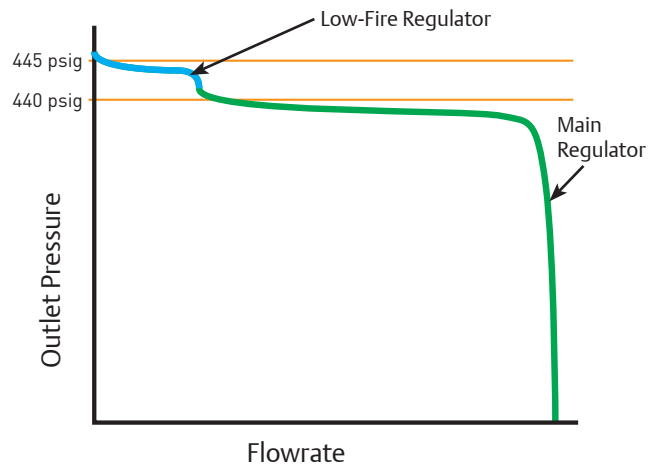


Figure 7. Low-Fire Regulator Setup Behavior

low demand loads, such as during plant startup. However, a second, smaller regulator, often called a low-fire regulator, can be added in parallel to handle the lower flow rates at a slightly higher pressure. The main regulator will pass any flow beyond the low-fire regulator's capacity. A schematic of this setup is shown in Figure 6. Staggering the main regulator and low-fire regulator setpoints ensures that the regulators do not fight for control. The main regulator should be set at a slightly lower pressure than the low-fire regulator keeping it closed but prepared to open once the flow demand exceeds the low-fire regulators capability.

Oversizing is the most common regulator selection issue. When a regulator is oversized, the valve plug remains close to the orifice. The limited plug clearance, coupled with the force of the upstream pressure, causes the regulator to cycle rapidly between open and closed. This high frequency cycling or instability, causes wear on the moving parts which can lead to component failure, loss of pressure control, and significant noise. Oversizing be avoided by selecting the smallest orifice size and lightest spring range that meets the maximum flow requirements at the minimum inlet pressure condition.

The load profile of the power plant must be considered when sizing and selecting a low-fire regulator. Because the main regulator must operate at flows exceeding the low-fire regulator's capacity, it is a best practice to select an appropriate transition point between the low-fire regulator and the main regulator. Taking the load profile into account leads to some stations with a much smaller low-fire regulator than main regulator while other stations will be closer in size, sometimes even the same size.

Product Selection Considerations

When selecting a means of pressure control for power plant natural gas pressure reducing stations, end users and station design engineers should consider the following factors.

Flow

Flow rate is arguably the most important controlled variable within a station feeding a gas-fueled power plant. The flow rate capability of the station must surpass the flow requirements of the plant at maximum load. The flow path of the station can contribute to pressure drops, which could lower the capacity of the station. Because of these principles, axial flow technologies have higher flow capacities than top-entry, globe body regulators of the same size.

Minimum Differential

Understanding the minimum differential pressure required for the operation of a pilot-operated valve is another key consideration when evaluating regulators for gas-fired power plant feed applications. Minimum transmission line pressures close to the turbine feed pressure can complicate sizing a regulator, because the regulator's minimum required differential pressure may not be achieved in that scenario. Pilot-operated regulators each have a published minimum differential requirement to achieve full travel. In general, the larger the diaphragm, the lower the differential requirement. This is one of the reasons wide-open monitor setups are more common than working monitor setups which take a second pressure cut. The pressure drop across the wide-open monitor regulator is important so axial flow regulators are commonly used because of their efficient flowpaths.

Shutoff

During a plant shutdown, bubble-tight shutoff is required. Ensuring regulators within the station have ANSI Class VIII shutoff rating will increase the safety and performance of the station. Operators should maintain a regulator preventive maintenance schedule to inspect and repair sealing surfaces of the regulator, such as the plug and orifice.

Accuracy

Tight pressure control is a necessity in power plant feed applications. The downstream turbines have high and low-pressure trip points, ensuring proper operation and preventing equipment damage, which would shut down the unit if the delivery pressure is not held within them. Choosing a regulator with tight pressure accuracy allows the setpoints of the overpressure protection, low-fire regulators, and redundant runs to be set closely together, permitting satisfactory station protection.

Speed of Response

Speed of response is also an important feature to keep in mind while designing natural gas stations to maintain tight pressure control even during flow demand transitions. Regulators have faster speed of response than control valves which must receive an electrical signal to reposition. Regulators have multiple options for improving speed of response if it is unsatisfactory such as pilots designed for quick opening speeds and pilot restriction options and booster pilots for speeding up closing speeds.

Noise

Large pressure drops and high flowrates emit a large amount of noise by nature of the application. This may or may not be an issue based on the location of the station in relation to populated areas or site requirements. Specifications of these stations vary but a common benchmark is 85 dB about 1m away. Turbulence inside the regulator or control valve produces additional noise. Designs with more efficient flow paths, like axial-flow regulators, produce less noise than other designs as shown in Figure 9. Some regulator types offer noise attenuation trims as options if noise is a point of concern.

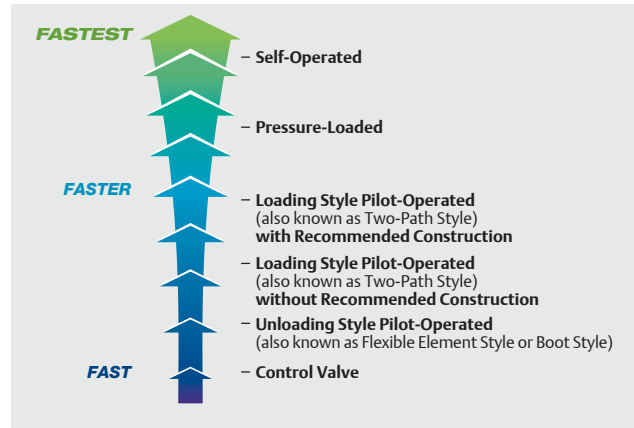


Figure 8. Speed of Response

Maintenance

Top-entry regulators with inline maintenance offer the best-in-class ease of maintenance. Maintenance tasks can be performed on these units without ever removing the body from the line. Axial flow regulators, while the maintenance tasks are simple with few pieces, have components that need to be removed from the line to perform maintenance. Control valves, on the other hand, can have various degrees of challenges when it comes to maintenance. For the control valve to perform optimally, the pneumatic control systems and all electrical components must be adequately maintained. If a station is buried underground, many maintenance items will require the valve to be unearthed, adding time and costs to completing these tasks. Many control valve models on the market today require the valve to be removed from the line.

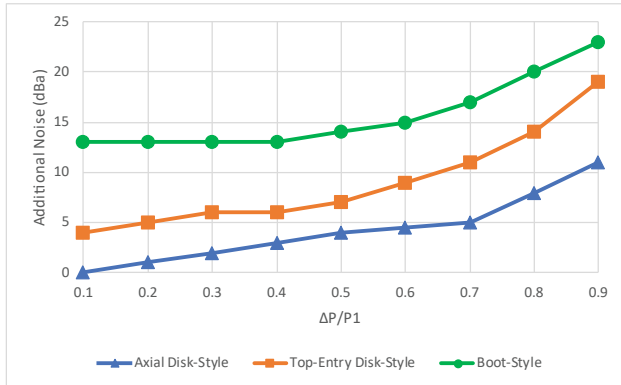


Figure 9. Sound Performance by Regulator Type

Emissions

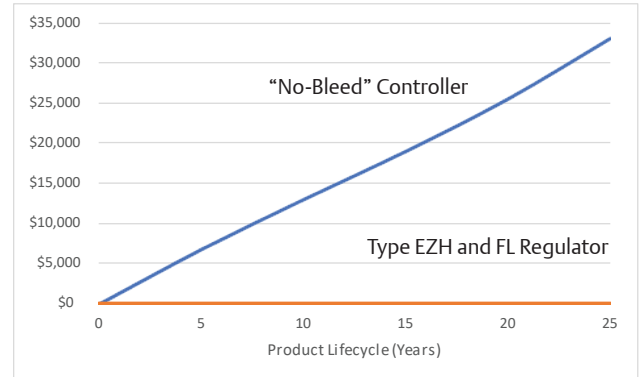
Regulators are self-contained devices: they do not release any natural gas into the atmosphere, which is desirable for minimizing fugitive emissions during operations, unlike control valves. The lost natural gas is an inefficiency that adds costs over time. Figure 10 shows the approximate costs of control valve emissions over time per zero steady-state bleed controller. Many controllers require a steady state bleed which would be even more cost.

Position Feedback

Wireless position feedback is available on a variety of regulators to communicate real-time regulator performance. This added feature gives operators an extra indication that the operator is behaving as expected during normal and transient operations.

Additional Overpressure Protection

Overpressure protection is an important aspect of safety as it pertains to these stations. In addition to a wide-open monitor as the primary form of overpressure protection, many choose to protect their equipment and personnel with a second layer of



1. Source: EPA – Directed Inspection and Maintenance at Gate Stations and Surface Facilities Report
 2. Source: EPA – Oil and Natural Gas Sector Pneumatic Devices Report; assuming \$7/Mcf natural gas price

Figure 10. Cost of Ownership by Control Device

overpressure protection equipment. A relief valve adds a second layer of defense and protects equipment from thermal expansion of trapped gas or regulator leakage.

Furthermore, slam-shut devices are also common overpressure devices used in natural gas stations. These units will completely block downstream flow after an overpressure or underpressure event is sensed downstream. Many pressure regulator designs offer options to couple these devices into the body of the regulator. A solenoid valve can also be added to connect the slam shut to an existing safety system to form a remote trip, ensuring that the regulating station shuts down quickly during a turbine trip.

Summary

As natural gas-fired power plants become more and more common as North America’s energy mix evolves, operators will need to better understand how reducing stations work. Regulators in these stations are a great option and offer flexibility of station design, ease of maintenance, reliability, and performance. The manufacturer’s application team can assist in sizing and selecting regulators for use in these stations to optimally feed the plant throughout its life cycle.

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