Single Valve Fuel Gas System Retrofits

A Petrotech, Inc. White Paper

Petrotech. Inc.

EXPERIENCE • CAPABILITY • EXECUTION

Corporate Headquarters

151 Brookhollow Esplanade
New Orleans, LA 70123

Phone: (504) 620 – 6600
Fax: (504) 620 – 6601
www.petrotechinc.com

Company Overview

Petrotech Incorporated (Petrotech), headquartered in New Orleans, Louisiana has been providing advanced turbomachinery and process control systems for more than 40 years. With facilities in Houston, Texas and Suffolk, United Kingdom, Petrotech provides a full range of products and services for rotating machinery control and instrumentation. Our products include integrated control systems for gas and steam turbines, generators, compressors, pumps and the associated ancillary equipment. We also provide sophisticated process control solutions around the rotating machinery that complement or replace DCS based plant controls. Our turnkey services include engineering design (software and hardware), control panel manufacturing, site I&E services, commissioning and startup.

Within the energy sector, Petrotech has installed control system solutions for oil & gas, petrochemical and power generation plants. We help our customers increase reliability, improve efficiency and reduce downtime. Over our 40 years, we have developed a library of mature control products and applications for centrifugal and reciprocating compressors anti-surge and process control, as well as gas, hydro and steam turbines. These applications have logged millions of hours controlling, optimizing and protecting the operation of a variety of rotating machinery.

Regardless of where in the energy chain Petrotech operates, our approach remains the same. To deliver superior customer satisfaction, that builds upon our reputation as a leader in rotating machinery controls.

Abstract

Many existing Frame 5 turbine fuel gas systems use two modulating valves to supply the correct amount of fuel to the gas turbine. The upstream valve (Speed Ratio Valve or SRV) controls the inlet pressure to the downstream valve (Fuel Control Valve or FCV). The FCV then acts to regulate fuel flow in response to a position demand signal generated by the turbine fuel regulator (TFR).

In 2-valve fuel control systems, the FCV inlet pressure setpoint is a function of turbine speed. Thus, at low turbine speeds, the SRV adjusts the FCV inlet pressure to some lower value. Conversely at high turbine speeds, the SRV adjusts the FCV inlet pressure to some higher value.

When retrofitting 2-valve fuel gas systems, it is possible to use a single fuel control valve solution. Single valve systems are less complex and more compact than 2-valve systems. They also eliminate the need for hydraulic systems. And single valve fuel gas systems do not require a fuel valve inlet pressure transmitter to operate.

Advances in actuator technology have made it possible to simplify fuel delivery systems into single valve systems which require only one electric FCV. Petrotech began installing such systems on GE Frame 5 turbines in the mid-1990s, using its patented mass flow control system and an Electro-Mechanical Servo Actuator (EMSA) valve. Modern fuel control valves, such as the Precision Engine Controls XVG and the Woodward GS16, are purpose-built for turbine fuel control applications and are field proven to perform reliably.

Figure 1 - Fuel Gas Cabinet prior to Single Fuel Control Valve Retrofit

As is the case for 2-valve systems, single valve systems are not inherently scaled to turbine speed. Thus, the speed scaling task of the SRV is transferred to the TFR logic. This ensures consistent light-off and improves acceleration during the start-up sequence. Single valve systems also simplify the TFR calibration because they do not require a fuel control valve inlet pressure controller.

Introduction

Although single valve systems have an additional valve (two block valves, a vent valve and the FCV) their operation is less complex compared to 2-valve systems, primarily because the SRV is not required. Additionally, the FCV inlet pressure transmitter and control logic are no longer required within the TFR. Since single valve systems are all electric, this precludes the need for a hydraulic oil system to actuate the valves. Thus, periodic recalibration as is required with pneumatic and hydraulic actuators and positioners is not necessary. The electric FCV used for single fuel valve systems also uses a 24VDC power supply, typically the same as the main control panel and does not require a separate power supply.

The 2-Valve Fuel Gas System

Before developing a control strategy to replace traditional 2-valve fuel systems with single valve systems, it is important to understand why 2-valve systems were used in the first place.

In 2-valve systems, the SRV's primary purpose is to lower the inlet pressure to the FCV during startup when low fuel flow is required. This in effect increases the resolution of the linear flow characteristic of the FCV at low fuel flow conditions. Without a SRV, conventional FCVs with outdated pneumatic or hydraulic control systems could not consistently provide proper fuel regulation for light-off and acceleration.

During light-off and acceleration, the fuel manifold pressure is relatively low, causing a high differential pressure across the FCV. In order to pass a low fuel flow across the valve at full fuel supply pressure, the FCV might only need to move millimeters from its seat. Thus making it more difficult to accurately regulate flowrate, due to position hysteresis and fouling. At the same light-off and acceleration conditions, the SRV reduces the FCV inlet pressure, causing the FCV to move further off of its seat, thus providing ample resolution.

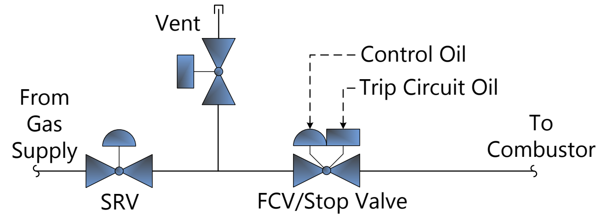

Figure 2 - 2-Valve Fuel Gas Schematic Diagram

The 2-valve system inherently corrects for variation in fuel supply pressure since the SRV regulates the inlet pressure to the FCV. Also, because the FCV inlet pressure setpoint is calculated as a function of turbine speed, the two-valve system corrects for variations in turbine speed at a given point in time in the startup sequence. For example, a weak starter will cause the firing speed to be slower. Slow firing speed means that less air flows through the turbine and that less gas is required to achieve the air/fuel mixture required for light off. In this scenario, the SRV lowers the FCV inlet pressure to account for the slower turbine speed.

The Single Valve Fuel Gas System

When compared to the 2-valve system, the primary differences are the presence of redundant on-off actuated shutoff valves and the absence of the SRV.

Petrotech deploys single valve fuel gas systems with redundant failsafe shutoff valves. In these systems the shutoff valves close in the event of power loss and the vent valve opens in the event of power loss. This arrangement simplifies purging, pressurization and valve stroke verification during the start sequence prior to light-off. It also complies with the requirements found in National Fire Protection Association (NFPA) standard 37. The redundant shutoff valves insure reliable interruption of the fuel gas supply when the gas turbine trips for any reason.

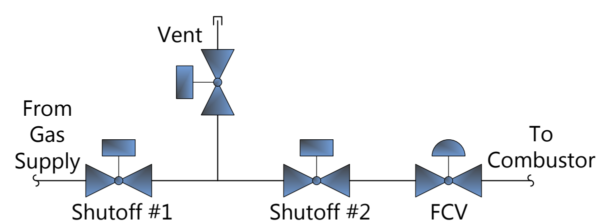

Figure 3- Single Valve Fuel Gas Schematic Diagram

Also known as electro-mechanical servo actuators, purpose built FCVs such as the Precision Engine Controls XVG and the Woodward GS16, include features which make them ideally suited to fuel control applications. Both valves utilize a modified equal percent trim. This trim insures that the valve's flowing capacity increases exponentially with increasing valve travel. Thus, providing appropriate pressure and low flow regulation during light-off and acceleration, as well as adequate capacity to accommodate high flow at full load.

These valves also include integrated position resolvers that are used as feedback to enable very precise positioning. And since the valve position is available to the TFR system as an analog signal, it is used for diagnostics and tracking verification. Onboard internal diagnostics also alert the control system if a problem is detected.

Figure 4 - Fuel Gas Cabinet after a retrofit to Single Fuel Control Valve Control System

Petrotech's TFR includes features which make single valve fuel systems reliable and robust. Even though the FCV operates in choked flow under operating conditions, fuel supply conditions still affect fuel mass flow delivered to the combustors. Therefore, the TFR system is designed to make it as tolerant to fuel and turbine variations as possible.

Soft Light-Off

Consistent and safe light off is achieved using a "soft light off" algorithm. After the TFR logic begins to fire the ignitor, the soft light off algorithm slowly ramps the FCV from its minimum position until the flame detection logic determines light-off. This ensures that only enough fuel is introduced into the combustors to achieve light off. Even with broad variations in fuel supply pressure, temperature and gas quality, the soft light off algorithm, insures safe and reliably consistent light off.

Fuel Pressure Correction

Fuel pressure correction schedules the startup fuel flow as a function of fuel supply pressure. This provides necessary pressure compensation for variations in the fuel supply pressure.

Speed Scaling

Speed scaling enables the TFR to condition the FCV output as a function of turbine speed. This accomplishes one of the functions of the speed ratio valve – that is, speed scaling corrects for variations in turbine speed at a given point in the startup sequence. Speed scaling prevents over-fueling the unit too early in the startup sequence by scaling FCV output downwards at lower turbine speeds, when too much fuel would merely increase the combustor temperatures rather than provide useful energy to increase the rotational speed.

Speed scaling also includes a unique feed-forward turbine acceleration approach. During turbine startup, while the unit accelerates to its rated speed, more speed allows the TFR to open the FCV further, which causes the unit to accelerate, which allows the TFR to open the FCV and so on. Not only does such a strategy tolerate wide variations in starter power with no changes necessary in the TFR configuration, it also enables the commissioning engineer to set how quickly the unit comes to speed by changing a single feed-forward gain value.