TURBINE TIPS

Pond And Lucier

Turbine Tips provided by **Pond and Lucier, LLC.** ®
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The Northeast Blackout of August 2003 & Hurricane Isabel of September 2003 prompt innovative gas-turbine-control-system solutions

Subject: Black Start Capability and Island Operation

Applies to: General Electric gas turbines: MS5001D, K, L and LA Package Power Plants
Applicable Control System: Young & Franklin Fuel Regulator

Overview:

In the early 1960s, General Electric offered a product called the "Package Power Plant." The PPP was a self-contained, gas-turbine-powered generator used primarily for emergency and peaking applications. It came with all of the auxiliaries required to operate independently. Most PPP had diesel starting engines. Furthermore, direct current (DC) motors powered auxiliary pumps and compressors as back-ups to the alternating current (AC) devices. These DC auxiliaries included a liquid fuel-forwarding pump, lube oil pump, starter motor for the diesel and hydraulic ratchet rotor turning mechanism. Also, a DC motor-driven generator set provided AC power to spark plugs, some critical controls like an exhaust temperature control amplifier and several control panel meters. In short, these PPP were designed with ***"black start"*** capability.

The most unique feature of these gas turbines was that in the case of **every start,** the control system ***defaulted*** to the battery power (DC) auxiliaries. This feature tested and verified the ability of the turbine to start when only battery power and liquid fuel was available, to try to achieve synchronous speed ***as if*** a local blackout had occurred. In some applications, a line undervoltage relay monitoring the power grid would initiate an emergency start signal for the gas turbine.

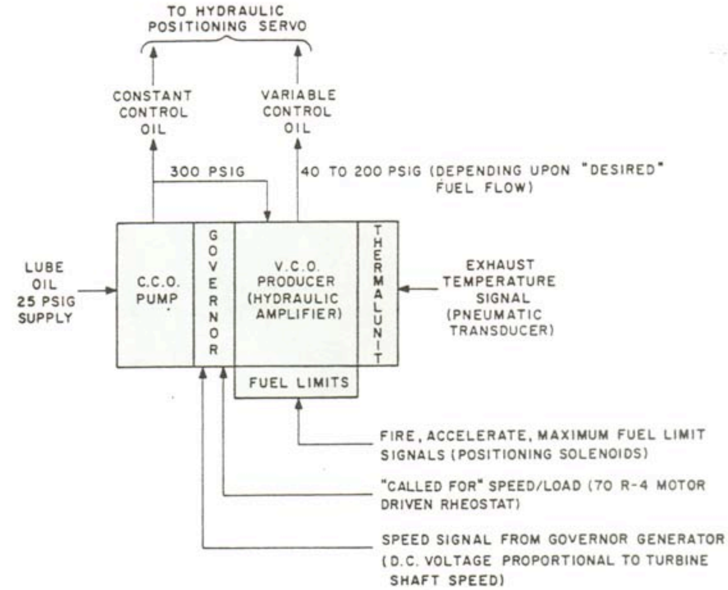

Fig. 1: Fuel Regulator Functional Diagram

Control System Upgrades:

The ***Fuel Regulator***, manufactured by Young & Franklin and shown in Fig. 2 below, is the primary controller used during the era on GE gas turbines. The governors were designed to operate only in the ***droop*** mode. This was done for load sharing on large power grids. No GE gas turbine/generators during the 1950s and 1960s were designed to operate in the ***isochronous*** mode. On smaller power systems, like islands, refineries and process plants, constant speed control was not readily available due to the idiosyncrasies of the fuel regulator. Times have changed. Modern systems can be married with controls that are 50 years old!

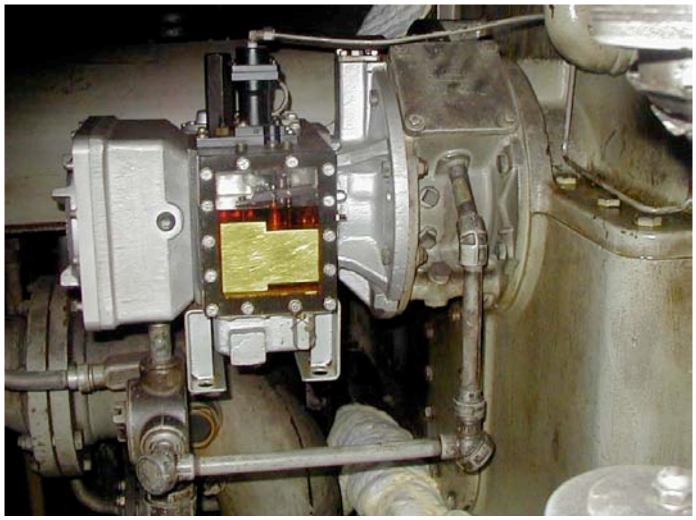

Fig. 2: Fuel Regulator on a typical MS5001 Gas Turbine

Please refer to the **Tip of the Month for February 2002** for more explanation of ***droop*** and ***isochronous*** operation.

The engineering staff of ***Pond And Lucier, LLC*** has designed a gas turbine control PLC-based system called the **PAL 5000.** See Fig. 3 below.

Fig. 3: PAL 5000 Control & Protection System at Liberal, KS

The **PAL 5000** utilizes a programmable logic controller (PLC) manufactured by Horner Electric for GE Fanuc and applied to control of GE gas turbines exclusively by PAL Engineering. It is an ideal fit. The control concept is to retain the Y&F fuel regulator but enhance it with features of modern technology. Thus, the PLC is used to receive signals from the gas turbine (e.g. shaft speed and turbine exhaust temperature) and send output current signals to the fuel regulator. A process variable (called Proportional-Integral-Derivative, PID) determines the rate of response needed to react to changes in speed with corrections in fuel demand. A variable control oil (VCO) pressure is the command signal from the fuel regulator to the gas valve or fuel pump.

For speed control, the governor solenoid, operating in the ***droop*** mode, receives two current signals from the **PAL 5000.** The **SLS-2** circuit board (patent pending) provides DC current signals for both the control and stabilizing coils. The gas turbine operator can raise and lower speed when "off line" and load whenever synchronized to the power grid. The stabilizing rheostat (original shown in Fig. 4) is replaced with a precision variable resistor for more precise control.

If the ***isochronous*** mode is selected for one on the gas turbines, the current signals to the control and stabilizing coils attempt to maintain turbine speed constant, while other turbines run in the ***droop*** mode to share load. Another PID loop is introduced for stability. The ***isoch*** machine adjusts its fuel flow whenever the gas turbine's speed deviates from 5105 rpm (as measured from the tachometer generator). This results in an essentially constant generator power output frequency (60.0 cycles per second). ***Droop*** machines, on the other hand, can be adjusted by a power plant operator to carry, distribute and/or share load demand, as desired.

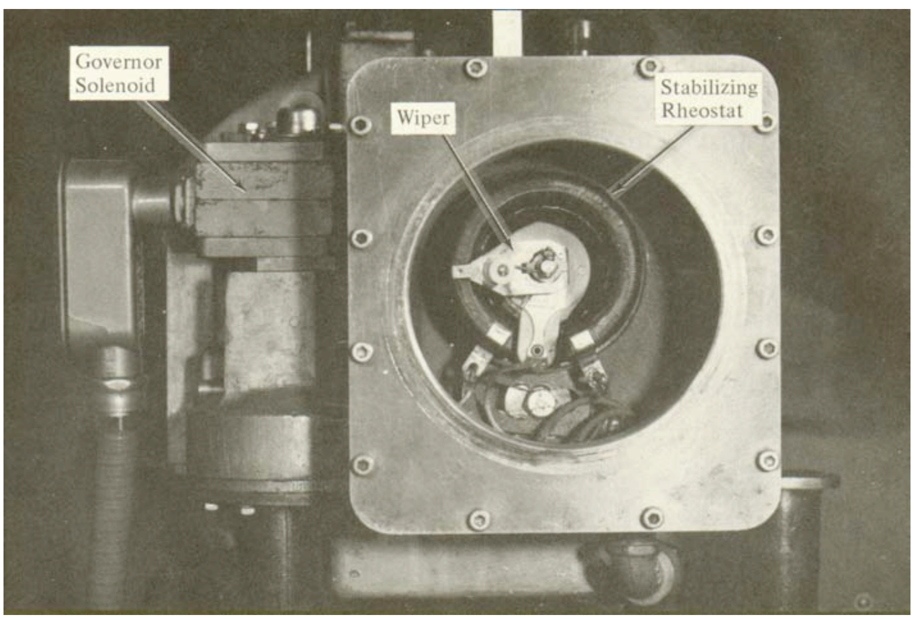

Fig. 4: Governor Solenoid and original Stabilizing Rheostat

The graphs in Fig. 5 represent a governor control with 4 percent ***droop*** (***droop*** is also known as ***speed regulation).*** Assume, for example, that all generators on a small electrical grid are operating with ***4 % droop***. As load is applied, the generators would tend to slow down. Since this is undesirable, the plant operator would have to raise the speed setpoints (increase fuel flow) to carry the additional load at the desired frequency (60.0 Hertz). In this scenario, the operating curve for the speed regulation would follow along the 4 percent ***droop*** lines. In theory, the speed could ***droop*** as much as 2.4 Hertz (that is, 60 x .04 = 2.4 Hertz) if the system load climbed from no load to full load.

A horizontal line in Fig. 5 represents ***isochronous*** (constant speed) control at 100% speed. If this mode is selected on one of the governors, this particular gas turbine will try to maintain **<u>constant speed</u>** whenever load demand changes. The raise/lower switch for the ***isoch*** turbine is typically disabled in this mode. Thus, it can tolerate **NO** changes in system frequency without a responding change in fuel flow to restore the frequency to 60.0 Hertz.

On the other hand, turbines with governors operating in the ***droop*** mode, running in synchronism with an ***isoch*** machine, would be able to raise or lower power output using their respective speed/load changers. Any increase in power demand on the system would immediately divert to the turbine in the ***isoch*** mode***,*** while the load on the ***droop*** machines would remain constant at their respective setpoints.

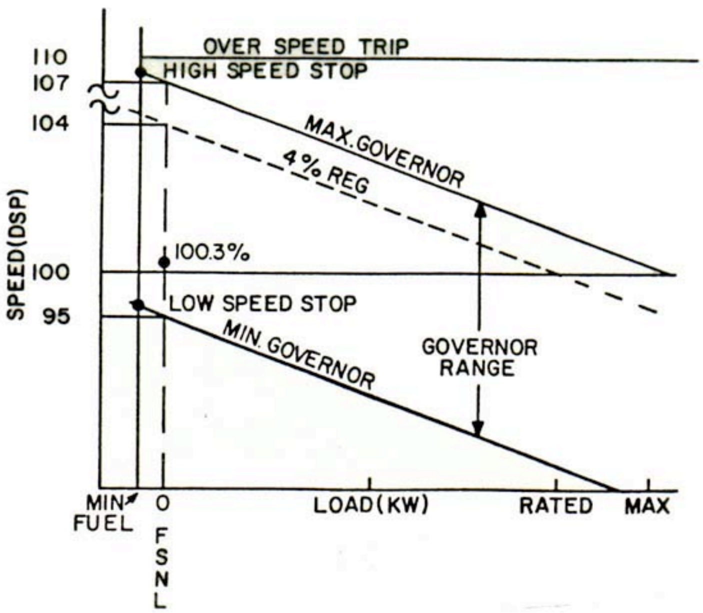

Fig. 5: 4 Percent Speed Regulation Versus Isochronous Operation

The **PAL 5000** control system now has the capability of controlling model MS5001D, K, L and LA gas turbines with Y&F Fuel Regulators in either the ***droop*** or ***isochronous*** modes. This is a breakthrough design change allowing these older GE gas turbine Package Power Plants to operate like modern machines at approximately 20 percent of the cost! Fuel Regulators may be over 50 years old in their applications to gas turbines, but modern technology can still keep them viable.

Contact ***PAL Engineering*** for more information on how this can be accomplished. Future Tips of the Month will explain further how the ***PAL 5000*** can work on your GE gas turbines.