# Optimization of Natural Gas Turbines for Greater Resiliency and Quick Starts for Adaptive Islanding

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## ABSTRACT

The HEP/DG Power Protector (with "Blue Button" reset technology) is a system of controls and sensors for optimizing the operation of a hybrid turbine cycle, where the turbine is mechanically coupled to the compressor by a common shaft and where the turbine is propelled by thermal energy from a coupled system, such as thermal energy storage or cathode and anode exhaust from a fuel cell, and where the compressor provides a pressurized oxidant gas to the thermal energy storage or cathode.

As long as the turbine cycle is a hybrid, the Power Protector can function and provide the operator protection from compressor stall.

This Power Protector system maintains the mass flow balance by changing the compressor dynamics and thereby increasing the safety margin of the turbomachinery and it decreases the likelihood of stalls in the hybrid power generation plant. It would work in hybrid systems with and without fuel cell integration.

The HEP/DG Power Protector controls compressed surge events by providing an oxidant gas to the compressor and withdrawing pressurized oxidant gas to the thermal component in the turbine cycle. In a fuel cell hybrid, for example, the pressurized oxidant gas is delivered to the fuel cell cathode and fuel is delivered to the fuel cell anode, and the cathode and anode exhaust is routed to the post combustor. The thermal exhaust from the coupled system is ported to the gas turbine, which is mechanically coupled to the compressor through a common shaft. (see Figure 1)

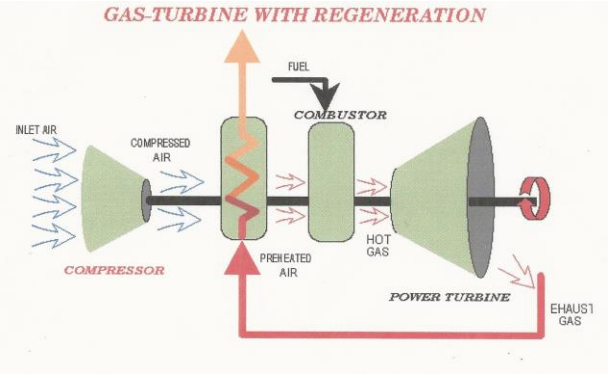


figure 1 above – single-shaft alignment

During the power production operation, various indications of an up-power transient beyond the limitations where the hybrid cycle can transition to a new steady-state may occur, which can lead to system failure. When such an indication is received (by the operator through audible cues) or directly by the Power Protector through audio sensors and processors, through the "Blue Button" circuitry some portion of the oxidant gas is diverted from the compressor outlet to the turbine inlet, until the hybrid system achieves a condition from which sustainable, steady-state operation may be achieved through the mechanically controlled intervention.

## Keywords

Hybrid Power, Natural Gas Turbines, Power Protection, Stall and Surge Protection, Compressor Protection

## 1. Detecting and Preventing Severe Up-Power Transients

Integrating fuel-cells with gas turbines and other components for transient operations increases the risk for equipment exposure to rapid and significant changes in process dynamics and performance that are primarily associated with fuel cell thermal management and compressor surge. Without rick management through advanced power controls, this situation can lead to severe fuel cell failure, shaft overspeed, and gas turbine damage. Sufficient dynamic control architectures need to be made to mitigate undesirable outcomes and that is why the "Blue Button" valve control has been introduced.

The indication of the up-power transient which provides the trigger point for the "Blue Button" compressor flue controls are likely to be: (1) an observed ramp-rate, (2) an automated or manual observation of a compressor surge, (3) a decrease in turbine speed, which drops below an expected value during normal operation, (4) operation outside of a stable envelope (as defined by a dynamic controller), and/or (5) other indicators as yet to be determined.

## 2. HEP/DG Power Protection Components


Figure 2 - The Control Panel

The basic control panel, including the above-referenced "Blue Button" manual control (located in the upper-right hand corner), is shown in Figure 2. (Shown is a working prototype.) The basic control panel is designed for manual operation and requires a human operator to be present and to be responsive to indicators of turbine/compressor imbalance as indicated in the above paragraph.

In the "advanced model," various ancillary components would be added to the Power Protection system; these addition components would include acoustic sensors and a high data acquisition system that would in effect automate the "blue button" function and reduce the need for oversight by a human operator on-site.

Other ancillary components for the installation include adaptations to the valve and by-pass line that would be inserted in the turbine cycle, along with a wiring harness that would connect the control panel (figure 2) with the valve (or flue) controls.

In Figure Three, the dynamic of the compressor (represented by the "pressure ratio" represented in the "Y" axis (compressor inlet and outlet pressure) follow a certain path that goes far away from the red "danger" line (the oblique line on the left).

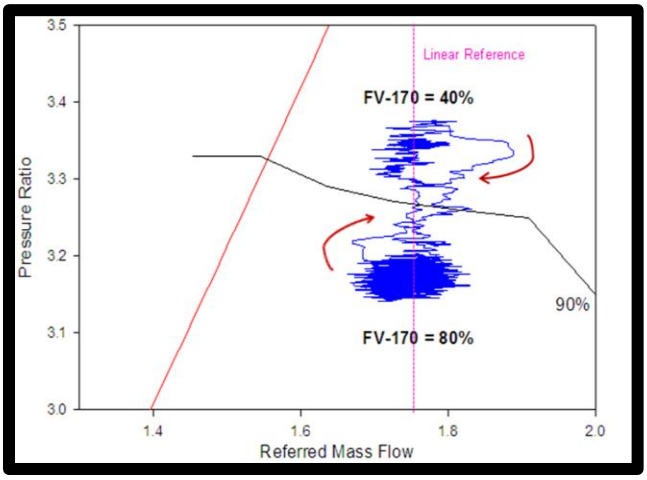


Figure Three above

When the Power Protector's "Blue Button" (valve controller) is activated, the mass flow through the compressor, which is generally kept constant, goes from 40% to 80% – this allows the safety margin to be increased while the flow balance through the compressor does not change.

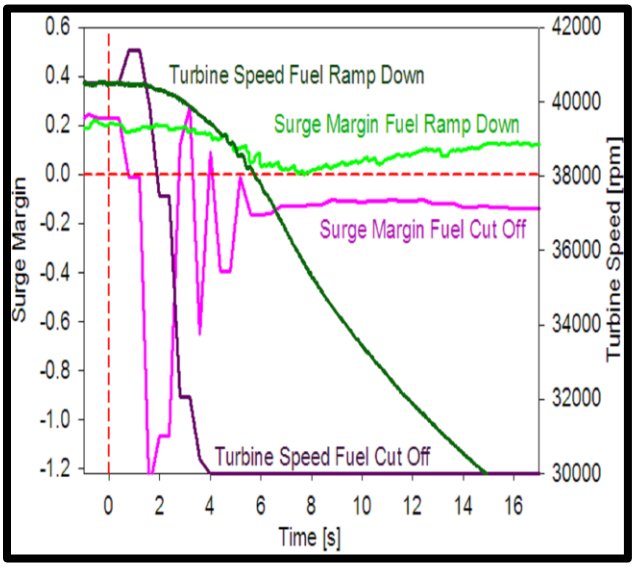


Figure 4 above

A test from the lab shows the EMERGENCY SHUTDOWN of the generation system with and without the actuation of the "Blue Button" (Valve Controller).

Figures Three and Four illustrate the successful operational results of the HEP/DG Power Protector while being tested in a lab environment.

## 3. Hybrid Power Generation Configurations that can be Protected with the "Blue Button" Valve Controller

- **Natural Gas (N.G.) Turbine and a Fuel Cell**
- **Concentrated Solar Power and N.G. Turbine**
- **Thermal Energy Storage and N.G. Turbine**
- **Geothermal and Natural Gas Turbine**

**As long as the turbine cycle is a hybrid configuration, then the HEP/DG Power Protector with its "Blue Button" Valve Controller technology can help the plant operator to:**

- **smoothly weather transient conditions**
- **permit wider swings in load adjustments**
- **minimize and prevent compressor surge**

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