GE Frame 5 - Black Start Capabilities

A Petrotech, Inc. White Paper

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Company Overview

Petrotech Incorporated (Petrotech), headquartered in New Orleans, Louisiana has been providing advanced turbomachinery and process control systems for more than half a century. With additional 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, reciprocating and centrifugal compressors, pumps and the associated ancillary systems found with these turbomachinery systems. We also provide sophisticated process control solutions around the rotating machinery that complement and enhance DCS based plant controls. Our turnkey services include engineering design (software and hardware), control panel fabrication, site I&E services, commissioning and startup.

Petrotech's control systems solutions have been successfully deployed to energy sectors, such as oil, gas, petrochemical and power generation industries. We help our customers increase reliability, improve efficiency and reduce downtime. Our library of mature software applications, purpose built for centrifugal compressor anti-surge and process control, gas turbine fuel regulation and steam turbine control have been developed and improved over a period of 40+ years and have logged millions of hours successfully controlling, optimizing the operation of and protecting a variety of rotating machinery applications.

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

Abstract

Black start generators allow the power producer to restart power production in the absence of an available power grid. Generators with black start capabilities are necessary for key generator systems in either industrial or utility applications to reestablish power production following a partial or system-wide blackout. In general, black start generators are not the large industrial turbine operated by the utilities for the purpose of baseline power supply. Rather they are smaller generator sets which must possess the capability to operate in isochronous mode until the power grid is restored. Then they must be able to switch over to droop mode if they are required to produce normal grid power.

This case study describes the modifications made to a GE Frame 5 Gas Turbine driven generator set to provide a Power System Operator (PSO) the ability to restart their large steam turbines following a blackout. The changes described include the modifications made by Petrotech to the generator system and to the gas turbine fuel control system, to assist the PSO in complying with their time sensitive restart requirements and increase the reliability of the GE Frame 5 Gas Turbine by installing modern micro-processor based controls.

Introduction

In response to previous system blackouts, a PSO implemented a plan to help alleviate problems associated with returning power to its network during future blackout scenarios. This particular "black start" program was undertaken following a system wide blackout which also affected much of the northeast United States and parts of Canada.

According to the PSO, black start capabilities are required to be built-in to the operation and sequencing of key generator units. The black start generator units will be used to initiate baseline power system restoration activities following a partial or system-wide blackout. These units possess the capability to start up without the presence of a synchronized grid and to provide the necessary auxiliary station power required to start and resume normal baseline power production. The PSO is also required to conduct black annual black start capability tests to ensure availability.

At this PSO, located in New York, U.S.A., Petrotech and operations personnel upgraded an older model GE Frame 5 Gas Turbine. The 25 Megawatt (MW) natural gas-fueled turbine provides black start capability for the gas-fired thermal station, consisting of two steam turbine generating units with power output of 335 and 491 MW. The GE Frame 5 Gas Turbine is controlled by a Petrotech Turbine Fuel Regulation (TFR).

Generator Control System

The original generator was fitted with an aging SCT/PPT (Saturable Current Transformer/Power Potential Transformer) excitation system originally supplied by the OEM. Client consultations and a field survey determined that the power magnetics (SCTs, PPTs, and linear rectifiers) were reliable. The voltage regulation system (AVR) however required updating to increase the unit reliability and to further integrate the generator control functions with the retrofitted TFR. Therefore, Petrotech procured a new AVR system that included a Digital Excitation Control System (DECS).

The microprocessor based DECS regulates the output voltage, VARs or Power Factor of a synchronous generator by controlling the amount of DC excitation applied to either the generator's main field or exciter field. It contains all the functionality necessary to limit, control and protect a generator from operating outside of the machine's capability. In addition to the DECS, a power rectifier, synchronization check relay, and an automatic synchronizer were also installed. The relay and synchronizer were also integrated with the new TFR system to allow the generator to start up in isochronous mode under no load conditions.

The deficiencies discovered with the original AVR and speed measurement equipment was that the PSO did not have the appropriate voltage and speed regulation required for a black start. When they started large motors on the steam units, the gas turbine was unable to reliability maintain the required voltage and frequency, thus the system would periodically trip on under-voltage or under-frequency. This would trip the equipment previously put into service and drastically slow down the startup process. When starting a large motor such as a 4000 hp induced draft fan motor or a 6000 hp start-up boiler feed pump, the smaller motors i.e., 50/100 hp motors could be subjected to large voltage or frequency swings.

Turbine Control System

In addition to the generator system equipment, and in order to facilitate more stable isochronous speed control, the gas turbine speed sensors were also upgraded. Faster speed sensing coupled with the new Petrotech TFR provided a reliable system capable of running either in isochronous or droop modes. The TFR system is a collection of mature function blocks with millions of hours of successful gas turbine fuel regulation over our 35+ years of operation. Originally written in 'C' source code and later converted to IEC-61131 compliant function blocks, TFR system(s) designed by Petrotech have been deployed on every make and model of gas turbine, including hundreds of GE Frame 5 mechanical and electrical drives.

With over 100 of those being electrical drive applications. Petrotech's advanced control software development has evolved to a fully open architecture that is transportable to all major commercially available hardware platforms.

The TFR system deployed for the case study project includes the capability to start-up and operate the generator in either isochronous or droop mode, and provide smooth transitions from one mode to the other under loaded operation. Additionally, during operation in isochronous mode, the TFR responds quickly to load rejections and load increases to maintain frequency at acceptable levels. The TFR logic stores the full speed no load PID loop parameters measured just prior to breaker closure. Thus, when the generator breaker trips under loaded operation, the full speed no load parameters are used to quickly trim the TFR response to avoid overspeed trips. Avoiding trips in this scenario enables plant operators to reestablish loaded operation without having

to wait for the generator speed to wind down and avoid an additional start sequence.

Human Machine Interface (HMI)

In addition to providing the engineering and design services required to modify the existing drawing set, controller application, TFR, and the new AVR, Petrotech also modified the existing HMI application. The HMI consists of a touchscreen panel-mounted computer. The HMI provides the operator with a graphics display, which presents control system data and system status. The layout of the front of the generator control panel changed very little. The main new component is the Digital Excitation Control System. The DECS has an alpha-numeric display that can be used to monitor current line voltage and other parameters. It also communicates with the controller to provide display and trending of generator performance data.

Petrotech created a black start screen to include the speed controller interface, voltage controller interface, detail display of the status of the DECS, and real-time trending for speed, exhaust gas temperature, generator voltage, and real power produced by the generator.

Conclusion

The upgraded control system allows for two principal operating modes — Connected to Utility Grid Mode (normal start mode) and Island Mode (black start mode). In the normal start mode, the speed of the turbine/ generator is dictated by the frequency of the grid, so the speed-governing portion of the TFR is set to droop operation. Droop operation provides excellent performance from the load control (MW control) point of view. Additionally, in droop mode, the excitation system assumes that the voltage of the generator is dictated by the grid, and works with the controller to provide MVAR control as desired. While running in this mode with the generator connected to the grid, all functions are available and the system can be safely put in auto operations, with either base or peak firing limits.

In the black start mode, the speed governing controls are set to isochronous operation and the excitation system controls the terminal voltage of the generator. This mode is used only while the generator is not connected to the grid, when precise frequency and voltage regulation is required, even during the starting inrush of large across the-line motors. Proper frequency regulation in isochronous mode is imperative to avoid damage to auxiliary equipment and enable reliable black start operation to assist operators on recovering from a partial or system wide blackout.

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