Wellfield/Powerplant Coordinated Control to Minimize Emissions

Tom McAuliffe

POWER Engineers

Keywords

Foundation Fieldbus, steamfield control, coordinated control, emissions, control system

ABSTRACT

The Western GeoPower project is a new nominal 38.5 MW geothermal power project located in the Geysers geothermal area; about 70 miles north of San Francisco, California. The steamfield consists of three wellpads with a total of nine steam-dominated production wells, two injection wells, three condensate collection tanks with forwarding pumps and miscellaneous auxiliary components and systems. The steam flow from each production well is monitored by a local transmitter and controlled by a motor operated valve (MOV).

California's strict emissions regulations requires a carefully coordinated startup/shutdown of the steamfield production well flows, the turbine bypass system (which discharges to the main condenser), the H_2S incinerator, and the initial purge of air from the steamfield piping system to the plant's rock muffler venting system. In this way, atmospheric venting of steam to the rock muffler is kept to a minimum.

A key feature of the Western GeoPower wellfield control strategy is the use of Foundation Fieldbus (FF) to implement local PID (proportional, integral, derivative) control in the field. These field devices (valves, transmitters, etc) have sufficient built in intelligence to allow them to communicate with each other via FF and to implement a coordinated PID control strategy with supervisory setpoint control from the central plant's control system. There is no need for a wellhead PLC (programmable logic controller) or other local dedicated control system. The field devices themselves are the control system. The result is a truly distributed control system.

The Western GeoPower Foundation Fieldbus based steamfield control system provides a cost effective and robust distributed control system. The control logic runs in distributed IP68 rated field devices which work together holistically and can continue to function autonomously even in the event of a total loss of communications back to the central plant control system. The plant's central control system software is used to configure the field device logic strategy, just as though the Foundation Fieldbus IO (input/output) points were directly hardwired to the central system. The result is a tightly integrated, rugged, steamfield control system that meets the project's challenging environmental requirements.

Motivation

California has very strict limits on the amount of H_2S laden steam that can be vented during the startup of the Western GeoPower geothermal power project. In order to meet these requirements it is vital that steam production startup be carefully coordinated with the plant startup such that all the wellfield steam can be routed through the main condenser so that the non condensable gases may flow onwards to the H_2S incinerator system. The challenge is that there is a sequence of operations and conditions that must take place prior to the condenser being ready to receive steam. Prior to synchronizing the turbine/generator to the grid, a turbine bypass system is used to divert the steam directly to the main condenser. But the condenser must be at brought to its normal operating vacuum in order for it to begin to receive steam.

First, one or several wells must be cracked slightly open in order to purge the steamfield piping of air and to begin to warm the pipeline and well casings. Once the system has been purged of air, the rock muffler atmospheric vent valves are driven closed and a small amount of steam pressure is allowed to build in the line. This small amount of steam pressure is sufficient to apply sealing steam to the turbine glands and to begin the vacuum pulling operation, but sufficiently low such that atmospheric venting is not required. Roughly 30 minutes after the vacuum pulling operation begins the condenser pressure is sufficiently low that the turbine bypass system, which discharges to the main condenser, may be placed into operation. At this point the production well flow rates may be ramped up at a rate designed to minimize well bore stresses while the steam pressure setpoint upstream of the turbine bypass is ramped up to normal operating conditions in anticipation of turbine/generator synchronization. During a normal plant shutdown, the production wells are ramped closed in coordination with the turbine and turbine bypass systems. In the event that there is a sudden loss of cooling water flow to the main condenser, the production wellheads must be ramped closed as quickly as possible in order to minimize atmospheric steam venting. Based upon the experience of other operators at the Geysers; the wellhead maximum opening ramp rate will be set at 2% of full load steam flow per minute up to 50% steam flow, 4% per minute between 50% and 75% steam flow, and 2% per minute above 75% steam flow. During a shutdown, a preliminary ramp rate of 9% per minute will be used. The final ramp rate settings will be determined based upon consultation with the reservoir engineer.

One common method for steamfield control is to utilize stand along controllers at each wellsite. This method has several drawbacks. A stand-alone PLC controller is relatively costly to purchase, install, and maintain. The PLC's copper components will be at significant risk of damage from the corrosive effects of H_2S gas and it can be difficult to ensure that the PLC's cabinet is airtight. The best PLC enclosures have an IP (International Protection) rating of 65 (protection from low pressure water jets with some ingress permitted). There is always some doubt about how well the cabinet door will continue to seal over years of use. Ambient air temperatures and sun impinging on the PLC enclosure can greatly shorten useful life of the electronics. Unless a dedicated cooling system is employed, the other electronic components inside the PLC enclosure (power supply, UPS, etc) can cause heat to build up inside the enclosure to the point that the PLC's rated operating temperature is exceeded. Maintaining the databases and programming of each wellsite PLC increases project cost and complexity.

Foundation Fieldbus field devices on the other hand, such as motor operated valves and transmitters, are designed for continuous operation outdoors under the most extreme conditions. These devices have a typical environmental rating of IP68 (permanent immersion under pressure). IP (International Protection) ratings are defined by the IEC (International Electrotechnical Commission) standard number 60529. Foundation Fieldbus is an open non-proprietary standard which is published and maintained by a non-profit organization (www.foundationfieldbus.org). This organization has developed the technology which can be used to network field device from a wide array of manufacturers together into a seamless whole. Each device contains logic function blocks that can work together with the other devices on the local network to implement a single comprehensive control strategy. An excellent source for further information on Foundation Fieldbus is the book *Fieldbuses for Process Control: Engineering, Operation and Maintenance* by Jonas Berge.

The Technology

The intention of the Foundation Fieldbus organization has been to develop an open system. Every device that carries the Foundation Fieldbus logo has a small file called a device descriptor (DD) file that may be downloaded from their website and imported into a suitable logic configuration application such as National Instruments NI-FBUS program. The logic function blocks that are provided for that device can then be dragged and dropped into a logic configuration application as desired. The logic is then uploaded to the field devices and they become fully aware of the other devices on the network and what each device's respective roll is in the overall control strategy.

The reality of the Foundation Fieldbus implementation within specific plant control system platforms is somewhat more nuanced. It is important to understand the relative strengths and weaknesses of the Foundation Fieldbus implementations of your competing control system vendors prior to issuing a procurement contract. In general, each control system manufacturer has certified specific manufacture's and models of devices for use with their system. The control system vendors have developed mapping functions from the open Foundation Fieldbus logic block implementation into their proprietary logic function blocks. Clients can request additional specific models be added to that list of certified devices, and generally these lists of approved devices will cover most users needs. Control system vendors have reduced the openness of the Foundation Fieldbus on their systems in order to allow the FF logic to be configured using their standard logic configuration packages. A single configuration application is used to program the entire logic covering both the hardwired in-plant IO along with the FF field devices. However, control system vendors should be encouraged and pressured by their clients to continue to improve their FF implementation with the ultimate goal of eliminating the need for manufacture/model specific logic function block mappings. Ideally, users should be able to import the FF.org DD files directly to their application and begin logic programming using all of the function block capabilities provided by the manufacturer of their field devices.

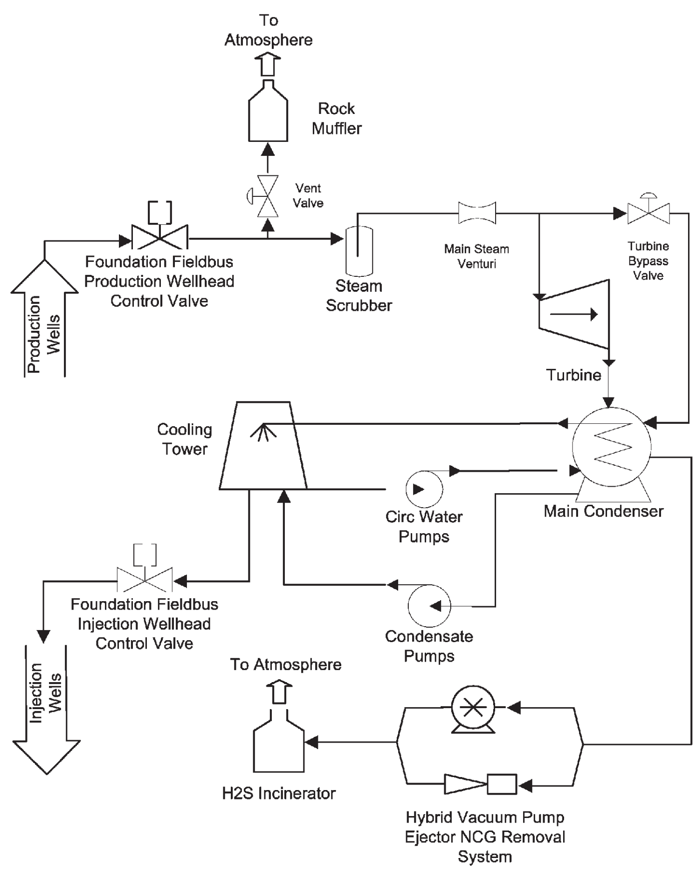

Figure 1. The basic process flow for the Western GeoPower project.

Project Specific Implementation

The new 38.5 MW Western GeoPower project consists of seven steam dominated production wells and two injection wells distributed over the steamfield's four remote well pad sites, a Fuji single admission steam turbine, a shell and tube steam surface main condenser, a turbine bypass system, a hybrid liquid ring and steam jet ejector NCG removal system, an NCG H_2S incinerator system, a wet cooling tower, and miscellaneous plant auxiliaries. The basic process flow for the Western GeoPower project is shown in Figure 1.

Foundation Fieldbus technology with the control logic executed in the field devices is used throughout the steamfield. The operator normally only provides supervisory setpoint control to these control loops, but may take manual control of the final field devices (condensate forwarding pumps and motor operated valves). The steamfield control loops include PID production well flow control, A cascaded control loop for reinjection (reinjection flow with a supervisory setpoint based on the sedimentation basin level), and on/off condensate collection tank level control.

Foundation Fieldbus technology allows the production wellhead MOVs (motor operated valves) to receive supervisory setpoints from the PCS (plant control system), monitor its local wellhead flow transmitter's process variable, and to execute a PID logic algorithm in order to maintain the flow at the desired setpoint, even if communications to the PCS are severed.

Ethernet based single-mode fiber optic communications are used to connect the central plant control system and local control panels at each wellpad. Each wellpad control panel contains a FF gateway device with a built in power supply filter, a 24VDC power supply, a UPS (a battery backed uninterruptible power supply), a fiber patch panel, a Hirschmann Ethernet rail switch (copper and fiber ports), and a Rosemount 848L FF logic transmitter with interposing relays. The 848L provides digital outputs for actuating the reinjection pump motor contactors.

During startups, the steam pressure is initially controlled by vented to a rock muffler. H_2S gas is entrained in the steam supply at a concentration of something in the range of 200 to 600 PPM. The Northern Sonoma County Air Pollution Control District (NSCAPCD) has jurisdiction over the permissible amount of H_2S released from the Western Geopower project. The NSCAPCD has set the Western GeoPower project's maximum allowed H_2S atmospheric emissions flow rate at 20 kg/hr. The full load steam flow rate to the plant is approximately 280 thousand kg/hr. Assuming a worst case scenario of 600 PPM H_2S in the steam there will be approximately 1.16 kg of H_2S in every 1000 kg of steam. The permissible rate of steam venting is therefore 17241 kg/hr or roughly 6 % of the nominal full load steam flow. During startups and shutdowns, the steamfield and power plant must be carefully coordinated in order to maintain the hourly average atmospheric venting to the rock muffler below approximately 6% of the full load steam flow.

Once turbine gland sealing steam and, subsequently, condenser vacuum has been established; the steam pressure may be controlled by venting to the condenser via the turbine bypass system. Pressure control by means of the turbine bypass system is greatly preferred because, in this operational mode, the H_2S non-condensable gases are contained and routed to the abatement system. Once the turbine has been started and synchronized to the grid, the turbine governing valves take over control of the steam pressure and the turbine bypass and rock muffler vent valves automatically close. In the event of a turbine trip, pressure control will revert to the turbine bypass system. If the turbine bypass system is unavailable, due to a lack of cooling water or condenser vacuum, the rock muffler vent valve will assume responsibility for control of the steam system's pressure and the production wellhead MOV's will quickly ramp.

During normal operation, the operator will place all three pressure control loops in automatic (turbine inlet pressure regulator, turbine bypass valve, and rock muffler vent valve). The turbine pressure control regulator will normally have the lowest setpoint, with the turbine bypass somewhat higher, and the rock muffler with the highest setpoint. These setpoints are selected based upon the preferred order of pressure control.

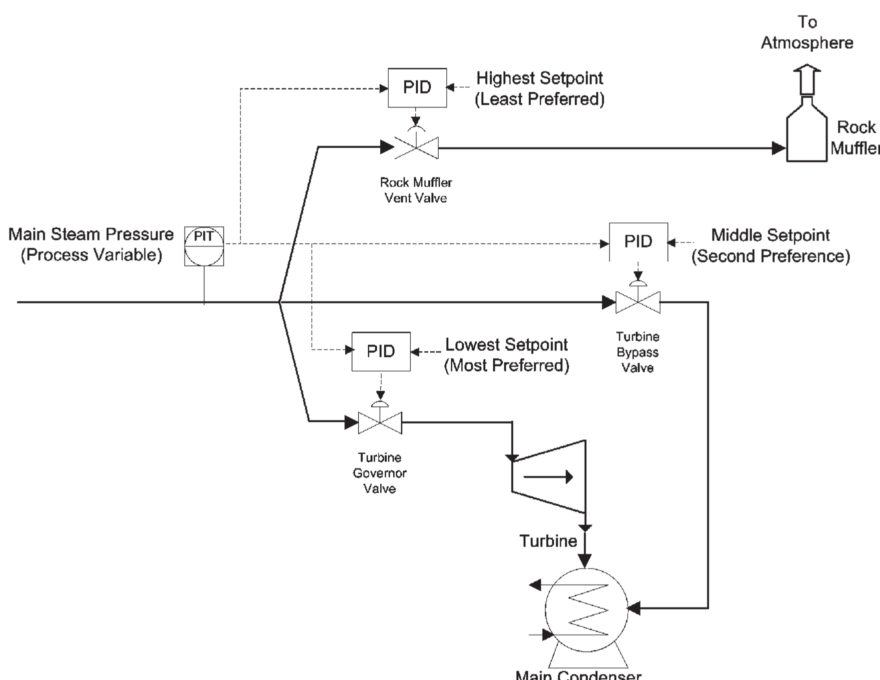

Figure 2.

In the event of a turbine trip, if the turbine bypass permissives have been met (condenser vacuum OK and at least one circulating water pump running), then the turbine bypass valve will open to control the steam pressure. If the turbine bypass system is not available for operation or the system pressure continues to rise, the rock muffler vent valves will begin to open. At the same time, the flow setpoints for all of the production wells will automatically ramp down to a minimum flow setpoint at a rate of about 9% of the full load steam flow per minute. The operator will can then manually close in the production wells either from the plant control system operator interface or manually at the wellhead.

An operator interface screen provides a table of flow setpoints for all of the production wells. The operator may enable/disable the flow from any well, enter a manual flow setpoint for that individual well, or enter flow percentage value for each well with respect to the total steam flow. A single master flow setpoint for the entire steamfield can be enabled and adjusted to raise/lower the total wellfield steam flow based upon each well's flow percentage value.

A sedimentation basin at the plant receives any excess water from the cycle or from storm runoff. This water is then reinjected into the reservoir into wells that are at an elevation that is approximately 800 feet below the level of this basin. The basin level is monitored by transmitters hardwired to the plant control system and the level controlled by Foundation Fieldbus motor operated valves at the injection wellheads. A cascaded PID control loop is used to maintain the sedimentation basin at setpoint. The operator enters a level setpoint for the sedimentation basin. A PID algorithm running in the central plant control system monitors the basin level and develops a desired injection flow setpoint. This flow setpoint is apportioned to each reinjection well that is currently in automatic mode, based upon a pre-defined table of injection well flow capacities. PID algorithms running in each injection well MOV monitor their local flow transmitter's process variable and automatically adjust their position to maintain the flow at the setpoint. The result is that all of the reinjection wells work together, and with the central plant control system, to regulate the total injection flow rate such that the sedimentation basin level is maintained at the desired setpoint.

Conclusions

The Foundation Fieldbus technology offers a cost effective, robust, and functionally rich solution to the steamfield control needs of the geothermal industry. Eliminating wellfield PLCs reduces overall costs and enhances system reliability. Control system vendors support a wide array of final field devices whose FF function blocks can be readily programmed into an overall control strategy as though they were directly hardwired to the central plant control system IO cabinets. Control system vendors should be encouraged to continue to improve their FF implementation in order to eliminate the need for mapping of the FF field device manufacturer's function blocks. The ultimate goal should be that the field devices device descriptor files could be downloaded from the www.foundationfieldbus.org website, imported into the control system vendor's logic configuration program, and all of the field devices function blocks would be available for use.