Foundation Fieldbus for Geothermal Steamfield Applications Control in the Field

Tom McAuliffe, P.E.

POWER Engineers, Inc.
Hailey, Idaho

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ABSTRACT

In 2001 the author presented a paper at the GRC conference describing a state-of-the-art steamfield control system that utilized micro-PLCs for local geothermal steamfield control. A self-healing serial communications fiber optic ring network was used to allow the central plant control system to execute supervisory control over these distributed micro-PLCs via Modbus protocol using serial communications.

In the intervening seven years, technology has evolved. Local process control with supervisory control from the DCS remains at the core of today's system. However, we now recommend executing the local control logic in the final control element, typically a modulating control valve. The non-proprietary Foundation Fieldbus technology provides the best and only means readily available today to accomplish this goal.

Introduction

Control system platforms have evolved a great deal over the years. Beginning in the early 1960's computer based process control systems first appeared. These first systems were referred to as DDC (direct digital control) systems. These early systems had the disadvantage that a single point of failure, the central computer, would shut down the entire process. In the mid 1970's the first DCS's (distributed control systems) emerged on the market. These DCS systems were designed to have greater reliability by having redundant processors and power supplies and by distributing the control logic over multiple processors. The first PLC's (programmable logic controllers) emerged at roughly the same time as the first DCS's. PLC's were designed to replace hardwired relay control logic. As a result, the ladder logic PLC programming interface had the same look and feel as the logic documentation of their hardwired relay predecessors. The driving factors behind the move to computer based control systems was to make it easier to make logic changes and to simplify maintenance and troubleshooting. DCS's were developed for analog process control applications, which are typically programmed using a function block style programming language, whereas PLC's were developed for discrete logic applications, typically programmed using a ladder logic programming language.

With the evolution of computing technology, the first hybrid control systems began to appear in the early 1990's. The concept was to reduce hardware costs by using PLC components which could be programmed using DCS *or* PLC style software. The hybrid control system manufacturers would often place limits on the quantity of I/O that these systems could handle in order to not compete with their full-blown DCS systems. Today the lines have blurred to the point where it is almost impossible to differentiate between many PLC's and DCS's. Because of this, our preference today is to refer to control systems as PCS (plant control systems).

Plant owners became increasingly frustrated with the proprietary nature of their control systems. It appeared that control systems vendors were intentionally keep their technology proprietary in order to lock their clients into their systems. The IEC 1131-3 standard was, at least in part, an effort by users to force manufacturers to adhere to a standardized programming environment. The IEC 1131-3 defines standards for five programming languages including the most widely used ladder logic and function block programming languages. Perhaps a bigger impact on standardization has occurred due to the overwhelming momentum of the Ethernet technology. A further move towards standardization has been the evolution of Foundation Fieldbus technology. Foundation Fieldbus (FF) is an open, non-proprietary digital communications protocol designed to replace the traditional 4-20 mA instrumentation signals. The FF standards are maintained by the non-profit FF organization, www.fieldbus.org. There are two variants of FF: H1 is used for multi-drop field instrumentation networks and HSE (high speed Ethernet) which is used for linking H1 segments to the higher level host systems. Foundation Fieldbus is unique among the Fieldbus communications protocols in that it supports executing logic in the field devices. This execution of logic in the final field device using Foundation Fieldbus is the subject of this paper.

Discussion

Some control system and instrumentation vendors have been promoting the use of Foundation Fieldbus (FF) for a number of years now. The arguments in favor of FF typically center on reduced wiring costs or on the ability to extract more information from the field instrumentation and control valves than is possible with the traditional 4-20 mA loop. With FF, up to 12 instruments can be multi-dropped on a single pair of wires. The oil and gas industry has recently been using FF extensively, but the power generation industry has been slow to embrace FF. FF requires more knowledge on the part of their plant instrument technicians and the promised wiring cost savings are somewhat offset by the greater cost for designing the FF system. FF can provide data on the health of the field devices, but apparently plant owners have not felt there is enough value in this feature to make the jump to this new technology. What is generally not widely known by either the vendors or the end users is that FF enables true local PID (proportional/integral/derivative) control to be executed in the field devices themselves – *true distributed control*. This feature offers great promise for the geothermal industry's steamfield process control loops.

Typically only one or two simple PID control loops are needed at widely scattered geothermal steamfield wellsites. PID control is the most commonly used algorithm for analog processes, such as controlling the level in a steamfield separator. The controller output to a valve is related to the error between the measured process variable and the desired value (setpoint). This output normally includes one term that is directly proportional to the error and another that is proportional to the intergral with respect to time of the error. Occasionally a third term is used that is proportional to the rate of change of the error (derivative).

By executing the PID control in the final element (the control valve), the local steamfield PLC is eliminated which results in a significant cost savings, enhanced reliability, and reduced system complexity. The plant control technicians still need to learn the Foundation Fieldbus technology, but this is a truly open non-vendor specific system that uses simple drag and drop function block logic configuration. Another advantage, steamfield motor operated valves are typically rated as IP68 (continuously submersible), which means that their Foundation Fieldbus electronics are essentially immune to H_2S attack. A local enclosure for the Foundation Fieldbus gateway, power supply, UPS, and fiber optic converter (or Ethernet radio) are still required but, due to the smaller size required, could more easily be sealed against H_2S ingress. And note, only the power supply, control valve, and a process variable transmitter is crucial to the continuing operation of the local process control loops.

An FF H1 network consists of a FF power supply (typically 19VDC), a host linking device that serves as a gateway between the central control system host (typically a DCS or PLC) and the field devices on a multi-drop wiring segment. The FF system uses a multi-drop trunk-and-spur architecture. The same twisted shielded wiring used with traditional 4-20 mA systems is used. If 18 AWG wiring is used, the maximum segment length allowed is 1,900 meters, but this distance is reduced based upon the number of devices connected to the segment and length of each spur.

The maximum number of externally powered devices on an H1 link is 32, whereas the maximum allowed if all the devices draw their power from the segment bus is 12. Every segment needs to be evaluated and designed on a case-by-case basis depending upon the number of devices, the power draw for each device, and the length (resistance) of each wiring segment on the link. A typical FF segment that might be implemented at a geothermal well-site is shown below:

Each FF segment requires one link active scheduler (LAS) whose job it is to regulate the communications traffic on the bus. The Foundation Fieldbus protocol supports publish/subscribe, client/server, and event notification methods. Based upon a pre-defined schedule, the LAS grants permission to each device in turn to publish its information to the bus. All other devices on the bus listen to the published data and read it into memory (subscribe) if the data is required for their use. Client/server methods are typically used for communications to the DCS host. Event notification is used for alarming and trending purposes.

Each device on the bus may have link master capability but only one may serve as the LAS at any given time, the others serve as backups. Upon a failure of the primary LAS, the next link master on the segment would automatically take over. Typically, the host gateway would serve as the primary link master, the final control

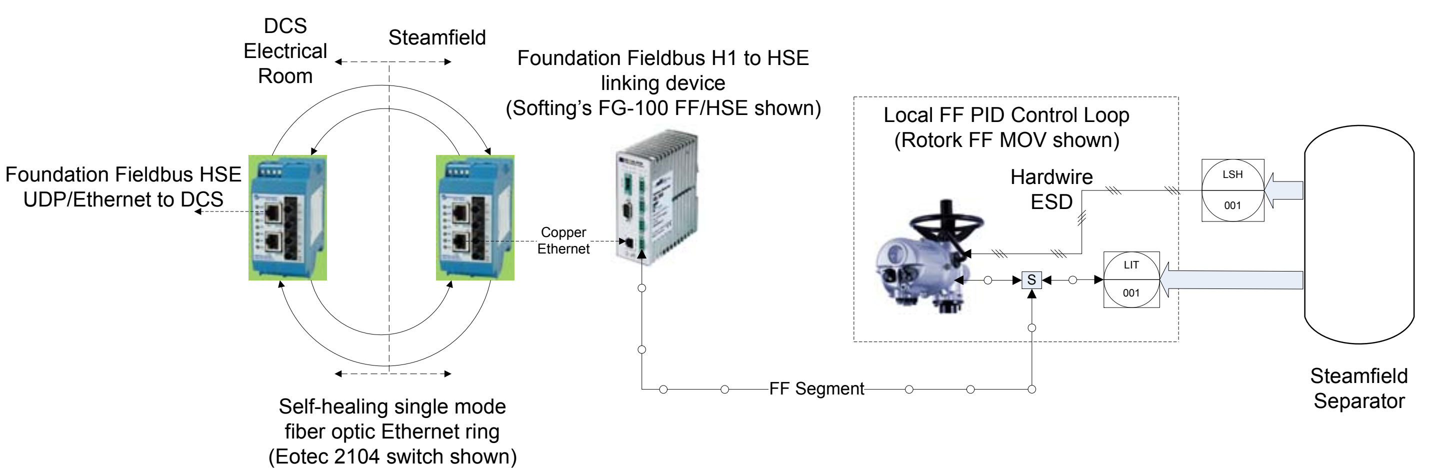

Figure 1. Typical segment showing the key hardware components.

element (typically a motor-operated valve) as the secondary, and the level or pressure transmitter (measuring the process variable being controlled) as the tertiary.

There are a number of vendors that make H1 to HSE linking devices that could be used at the local geothermal wellsites; ABB, Softing's FG-100 FF/HSE, Rockwell Automation's 1757-FFLD, National Instrument's FBUS-HSE/H1, and SMAR's DF63 module in their modular DFI302 system are several that this author is aware of. These devices provide two to four H1 FF segments. An RJ45 Ethernet port connects to the DCS Host typically via a self-healing ring fiber optic modem or an Ethernet radio. Configuration software such as National Instruments NI-FBUS Configurator, ABB's PPA, SMAR's SYSCON, or Rockwell's RSFieldbus software is used to configure the logic in the final field devices. The point is that FF is an open system where any vendor's field device can be programmed by any vendors software application. The software must be tested by and adhere to the standards set by the independant FF organization.

The Foundation Fieldbus specification includes twenty-one standard function blocks. The FF organization tests and certifies each manufacturer's field devices and standardized function blocks such as AI, AO, DI, DO, PID, Manual Loader, etc., as complying with the FF specification. The manufacturers publish device descriptor (DD) files that are downloaded and used to develop a control strategy using third party configuration software. Jonas Berge's book *Fieldbuses for Process Control* offers an excellent overview of Fieldbus technology. Rosemount's Foundation Fieldbus Blocks publication (www.emersonprocess.com/rosemount/document/man/4783b00j.pdf) offers an excellent overview of the standard Foundation Fieldbus function blocks available.

Configuring an application specific control strategy is as simple as importing the vendor specific DD files into the configurator program, dragging and dropping the icons for the devices to be used into the "Configuration Tree" for the segment being configured, opening up a sample control templates (cascade, ratio, PID, etc), right-clicking on each function block in the template, and replacing it with a block from one of the manufacturers devices specific to your project. Device Descriptor are a set of files published by each FF manufacturer and tested and certified by the FF Organization that provides information specific to that device. In theory, the DD files allow any vendor's host system (typically an operator workstation) to seamlessly access data from any vendor's field device.

There are a number of features built into the FF standard. For example, integral windup is automatically handled by the FF specification. Integral windup occurs when an actuator reaches the

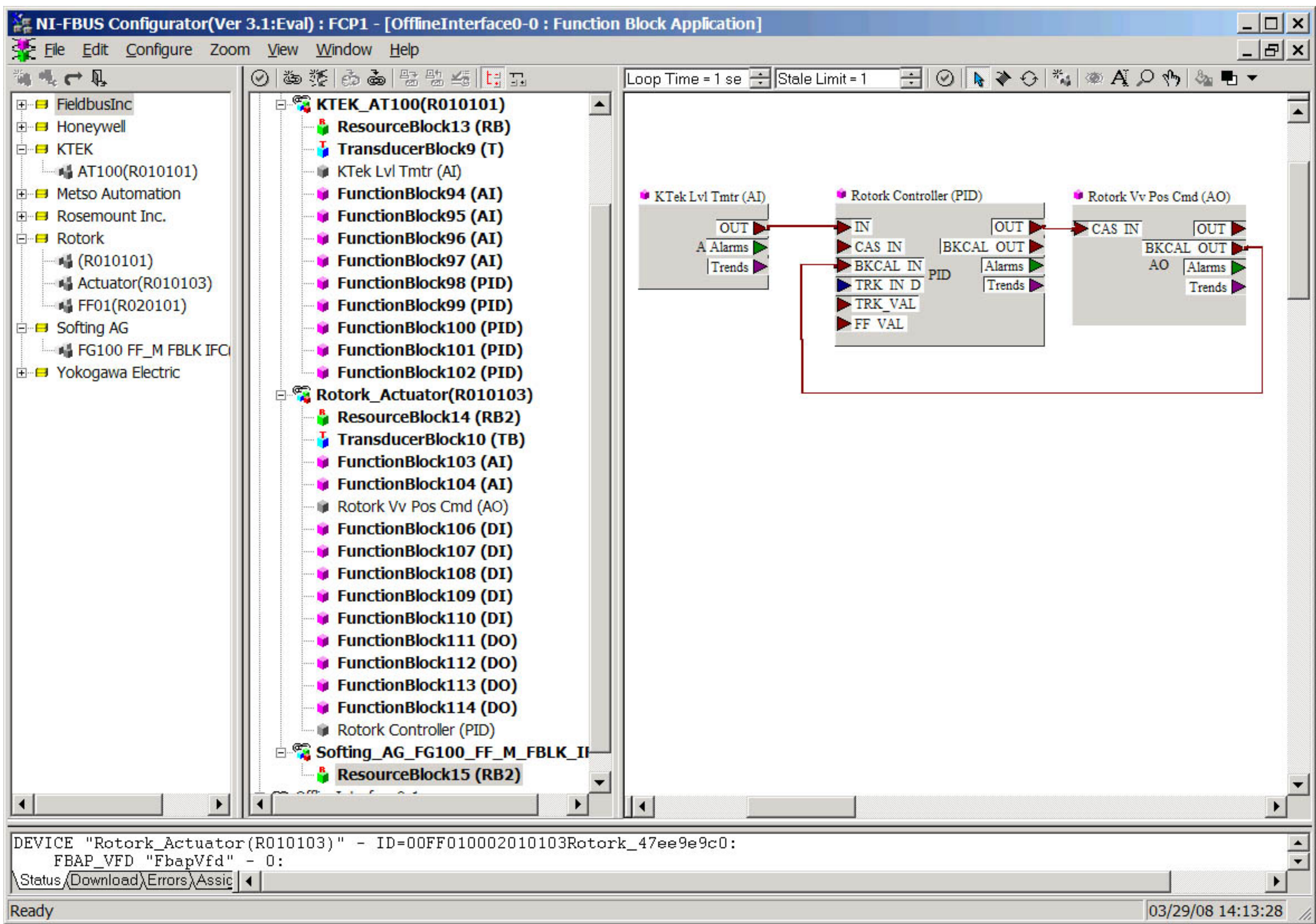

Figure 2. NI-FBUS configurator screenshot.

end of its travel, fully opened or fully closed, but an error remains between the setpoint and the process variable. Without integral windup protection, the PID controller will continue to integrate this error over time even though the valve cannot move. The result is that even if the error goes away it will take some time for the valve to move away from its end of travel position. With the FF built in windup protection, the end device (typically a motor operated valve) knows when it has reached the end of its travel and the integral term of the PID controller is automatically turned off without any end user specific programming required. Another feature of FF is that a failure of the process variable transmitter is identified immediately in a single scan cycle and the PID controller can be configured to immediately revert to a safe output. The following figure shows a typical logic configuration screenshot:

One area where the valve manufacturers could use improvement is the availability of ISEL (signal selector) and SGCR (signal characterizer) blocks in their valve positioner's Foundation Fieldbus implementation. All the valve manufacturer's generally have PID, AI, AO, DI and DO function blocks available but not always the ISEL and SGCR blocks. An ISEL block would allow for triple redundant transmitters to be used as the process variable input to the PID controller using a median select algorithm. This would enhance the reliability of the control loop. An SGCR block used to linearize the PID block's output versus valve flow would make the controller's tuning parameters work well over the entire operating range. A valve's flow versus percent opening curve will generally exhibit an S shape. The curve is flat for the first 10 to 15% opening, then there is a relatively steep linear portion (the sweet spot portion of the curve), then a relatively flat section above about 70% open. Linearization could be accomplished using a signal characterization curve that is the reciprocal of the flow versus percent opening curve.

Conclusions

For geothermal steamfield applications that typically require only one or two PID control loops at multiple widely scattered wellsites, Foundation Fieldbus provides an extremely elegant and robust solution. The PID control logic is executed in the final field device, typically a motor-operated valve regulating the level in a steamfield separator. A FF device (such as a level transmitter) on the same H1 segment as the MOV provides the PID loop's process variable. A DCS Host gateway device monitors the process but is not critical to its operation. The only critical items are the field devices themselves (level transmitter and valve) and the segment power supply. The PID controller in the final field device is safe from H_2S exposure inside the control valve's IP68 enclosure (rated for continuous submersion). The need for a local PLC with its associated cost, complication, and relatively large (less easily sealed) enclosure is eliminated. Valve manufacturers should be encouraged to add ISEL and SGCR blocks to their Foundation Fieldbus implementation. These additions would improve the reliability and controllability of their Foundation Fieldbus PID controller implementations. It is recommended that geothermal power plant owners consider applying Foundation Fieldbus for the local control of their geothermal steamfield wellsites.