AN ENGINEERING & CONSTRUCTION FIRM TACKLES FOUNDATION FIELDBUS

Kvaerner Shares Experience With Designing Field-Based Control Architectures.

By Andrew Houghton and David Hyde

Foundation fieldbus is quickly gaining acceptance in process automation and control. Over the past two years, several end users have written stories and papers describing new and upgraded automation systems that depend partly or entirely on fieldbus devices. While initial fieldbus installations tended to be nervously watched trials and demonstrations running non-critical processes, more recent applications have successfully attacked mainstream controls projects.

Houston-based Kvaerner's experiences in recently completing the development of a major chemical plant application show that IEC 61158 Foundation fieldbus has definitely achieved prime-time status, not only for user-developed projects but also for confident acceptance by Engineering & Construction firms. To be successful, however, we found that E&C companies need to change their working practices and develop new procedures and tools to make the leap from conventional DCS techniques to the scalable, field-based automation architectures permitted by fieldbus.

Host of Advantages

When conceived, fieldbus technology was envisioned to supersede 4-20 mA signal transmission. But it's become much more. Fieldbus devices are not limited to simply transmitting the process measurement, or even incrementally offering diagnostic and configuration information. Fieldbus is a sophisticated peer-to-peer control network. Each device on the network is an intelligent and interactive computer that monitors both the process and its own health. Fieldbus additionally allows process control at the device level, where elements of a control strategy can be executed in the field. For example, PID control may be executed in a transmitter or valve controller.

Through specified function blocks, Foundation fieldbus offers functions such as an input selector (min, max, or average PV), split range, or a signal characterizer to be implemented within the field device, regardless of vendor or instrument type. Control strategies involving these functions, as well as cascade relationships between strategies, are now possible in the field.

Moving control functions out of the process controller and into the field enables true distributed control and device-direct interactions. The process control system connected to the fieldbus segment then acts as the reporting mechanism to the operator. Field-based architecture also reserves the horsepower of the process controller for the higher tasks only it can do. The overall result is better performing automation. Control algorithm location is transparent to operators viewing workstation displays.

Fieldbus technology offers other freedoms as well. Segments support both bus and externally-powered devices. Fieldbus products are available for FM Class I, Div. 2 and Class I, Div. 1 hazardous areas. Contention-free fieldbus communications produce deterministic monitoring, calculations, and control. Further, Foundation fieldbus devices are interoperable among device and control system suppliers.

On the last point, interoperability is certified through device functional testing by the Fieldbus Foundation, an independent, non-profit trade organization. Registered devices are listed at www.foundationfieldbus.org; new additions are posted regularly. A good sign: We've found vendors are receptive to user input on future fieldbus products and functions. One caveat, though, is that vendors tend to be overly optimistic about when new products will become available.

Several end users have been conducting in-house tests and have verified that yes, fieldbus technology does work; and yes, instruments from different vendors do meet interoperability requirements. Now that the technology is maturing, the next stage in the cycle is widespread commercial deployment. Industry must refocus attention from developing the technology to furthering the implementation and smoothing the mainstream adoption of this disruptive technology.

Rethinking Process Control

We use the term disruptive technology to describe the adoption of fieldbus because the technology cannot be installed by a gradual series of small steps over time. Rather, the technology requires a complete restructuring of control system implementation.

A divide no longer exists between field instrumentation and the control system, as it has with DCSs. The control system and the field instrumentation must be engineered together. We call the end result of this combined engineering effort the Plant Automation System. PAS architecture makes a conventional DCS look very non-distributed.

The notion of input and output channels disappears with fieldbus. Devices are effectively wired in parallel on an H1 segment, and they share a single port on a process controller's fieldbus communications module. A shielded-pair

Foundation fieldbus H1 segment communicates at 31.25 Kbps and can address as many as 32 fieldbus devices. A higher-speed segment based on Ethernet is under development.

Devices must communicate following a regimented schedule—known as the segment's macrocycle—so every device has a chance to speak freely without risk of collision. One portion of the macrocycle is assigned to calculation and control execution, while the remainder is reserved for time-sliced unsolicited reports for alarming and setpoint changes.

To make best use of the PAS architecture, careful selection of the control system vendor is vital. The system should be one developed from scratch for truly field-based control and designed with Foundation fieldbus in mind—not as a bolt-on extra. Today's most advanced control systems are based on process systems having integral fieldbus capabilities. Third-party fieldbus configuration tools may work with small control systems and for instrument test and calibration, but they don't provide an integrated configuration database, documentation, commissioning, and maintenance tools required for large and complex control schemes.

Several vendors offer Foundation fieldbus communications cards for their older DCS systems, and they state that these cards enable the older systems to handle fieldbus devices. While technically true, just adding an H1 card is not enough. If an effective PAS architecture is to be achieved, fieldbus device configuration must be fully integrated with control system configuration.

What Does It Mean to an E&C Firm?

With Foundation fieldbus now maturing, any company contemplating a new plant or a plant upgrade must consider the technology. There are just too many lifecycle benefits to be gained from the extensive capabilities of fieldbus in combination with a modern control system, powerful asset management techniques, and enterprise-wide planning tools.

But how well these end-user benefits mesh with the necessarily short-term interests of an E&C company is another matter. The focus of such a company is to engineer and/or build a plant or addition, get paid for the services provided, and be gone. E&C company shareholder value derives from performing the work well—and as quickly and cheaply as possible. Since the shortest distance between two points, so to say, is what you know best (which is not necessarily a straight line), an E&C company's objectives are best met through established procedures, standards, tools, and skills. Changing the design philosophy adds risk.

How can an E&C company control engineer then justify Foundation fieldbus if his client has no preference? Fieldbus benefits of reduced material cost and reduced commissioning time are countered by uncertainties in developing the tools, skills, and procedures required to implement the technology. The shortsighted answer is that fieldbus may only be used if mandated by the client.

The history of process control technology shows that it advances relentlessly. The successful E&C company is the one that recognizes process control trends and adapts as necessary to implement the advancing technology. Accepting that the industry is moving toward networking, the question no longer is, "Why should I use fieldbus?" but rather, "Why should I not use fieldbus?"

Kvaerner recognizes Foundation fieldbus as the next advance. Given the opportunity to employ it—with the assistance of a leading field-based automation vendor—on a project where process control is not on the critical path, how could we not jump at the chance for developing the skills, tools, and procedures?

A few quick observations before delving into the details. During any process plant design there are many iterations before the design is completed. The impact of these changes is accentuated while climbing the field-based automation learning curve, so it's vital that everyone in an E&C firm remain flexible. Designers and engineers must work more closely than ever.

Fieldbus expertise today resides mainly in the manufacturing vendors' engineering offices and their local sales and system integrator representatives. Know that the cost of a first fieldbus project should include an expert from one of these sources on the E&C team. Last, formal training in fieldbus and related technologies is absolutely essential for everyone on the E&C team.

Beginning the Project Execution

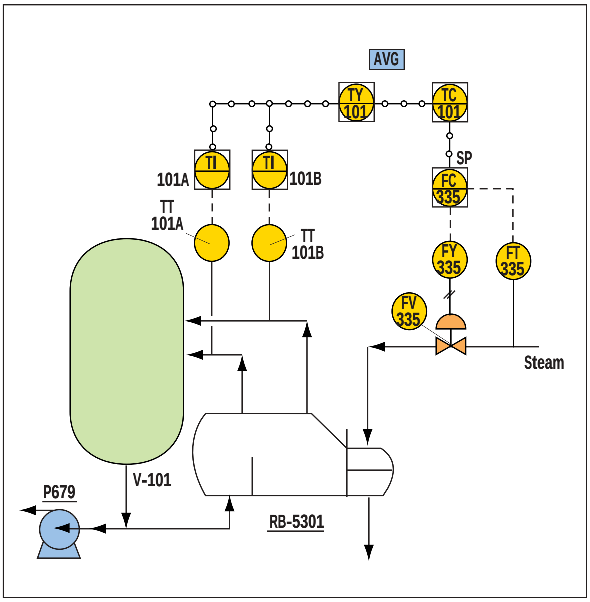
Selecting a DCS vendor in the past tended to be somewhat subjective. Familiarity, experience, personal contacts, etc., colored evaluations. But with Foundation fieldbus, you're not dealing with a DCS as commonly conceived. It's important to put the past aside and look closely at how well fieldbus integrates into all of the control systems you're evaluating. As mentioned earlier, fieldbus instrumentation works best if seamlessly unified with the control system. Make sure the system maximizes fieldbus's functional capabilities by providing the tools required for configuration of both the system and fieldbus devices.

Also, make sure the systems being evaluated don't provide an H1 card merely as another I/O type and therefore require the control system to perform all control functions. Unlike these systems, systems with truly distributed control allow faster control response (the control algorithm is executed entirely within one macrocycle), easier troubleshooting, more flexible control design, and simpler revisions and additions in the future.

To complement fieldbus, the most advanced process automation systems also provide communications modules for sensor-level buses. AS-Interface, DeviceNet, etc., are ideal for operating discrete equipment such as motor starters, switches, and the like. Reliance on both fieldbus and sensor buses can substantially reduce conventional hardwired I/O. Communications with other systems such as an emergency shutdown system and PLCs supplied by vendors as part of a mechanical package can also be handled by advanced process automation systems through open data representations such as OPC and Modbus.

FIGURE 1.

P&IDS RULE



THIS P&ID FOR A HYPOTHETICAL REBOILER ON A DISTILLATION COLUMN IS REFLECTED IN THE FIELDBUS SEGMENT DRAWING OF FIGURE 2. IF A CONTROL STRATEGY USES TT101'S INPUT SELECTOR BLOCK, A REPLACEMENT DEVICE MUST CONTAIN THAT FUNCTIONALITY OR THE BLOCK MUST BE MOVED.

Designing the Automation System

With conventional I/O, a fairly accurate count of I/O points and the numbers and types of I/O cards to be installed can be determined by reviewing P&IDs. With a fieldbus-centric design, the number of segments and therefore the number of H1 interface cards can only estimated before the fieldbus design is complete. Although the Fieldbus Foundation says as many as 32 devices can be addressed on a segment, the practical number is far fewer because of real-world limitations. This situation is further complicated by the increasing availability of multichannel and multivariable fieldbus transmitters.

Selecting the instrumentation for fieldbus-centric control systems involves considerable research. This is not only because of the significantly greater capabilities of fieldbus devices, but also because 4-20 mA and HART devices are often still required. Not every instrument type is available in a fieldbus version, and there remains a requirement for conventional instrumentation and I/O for safety instrumentation systems and certain extremely fast-response applications such as compressor anti-surge.

Questions About Documentation

Under the PAS philosophy, project documentation must be altered to reflect differences in physical and functional designs compared to conventional DCS controls. Careful consideration should be given to the purpose of each document type, where information needs to be shown, and if information can be consolidated onto fewer documents.

Engineering documents (loop sheets, P&IDs, and instrument data sheets) still have their place. But the question becomes, “How do we use these documents to best suit fieldbus functionality without compromising their scope and purpose in traditional projects?” It’s necessary to determine if any of these documents can be simplified or even eliminated, and if additional documents might be needed.

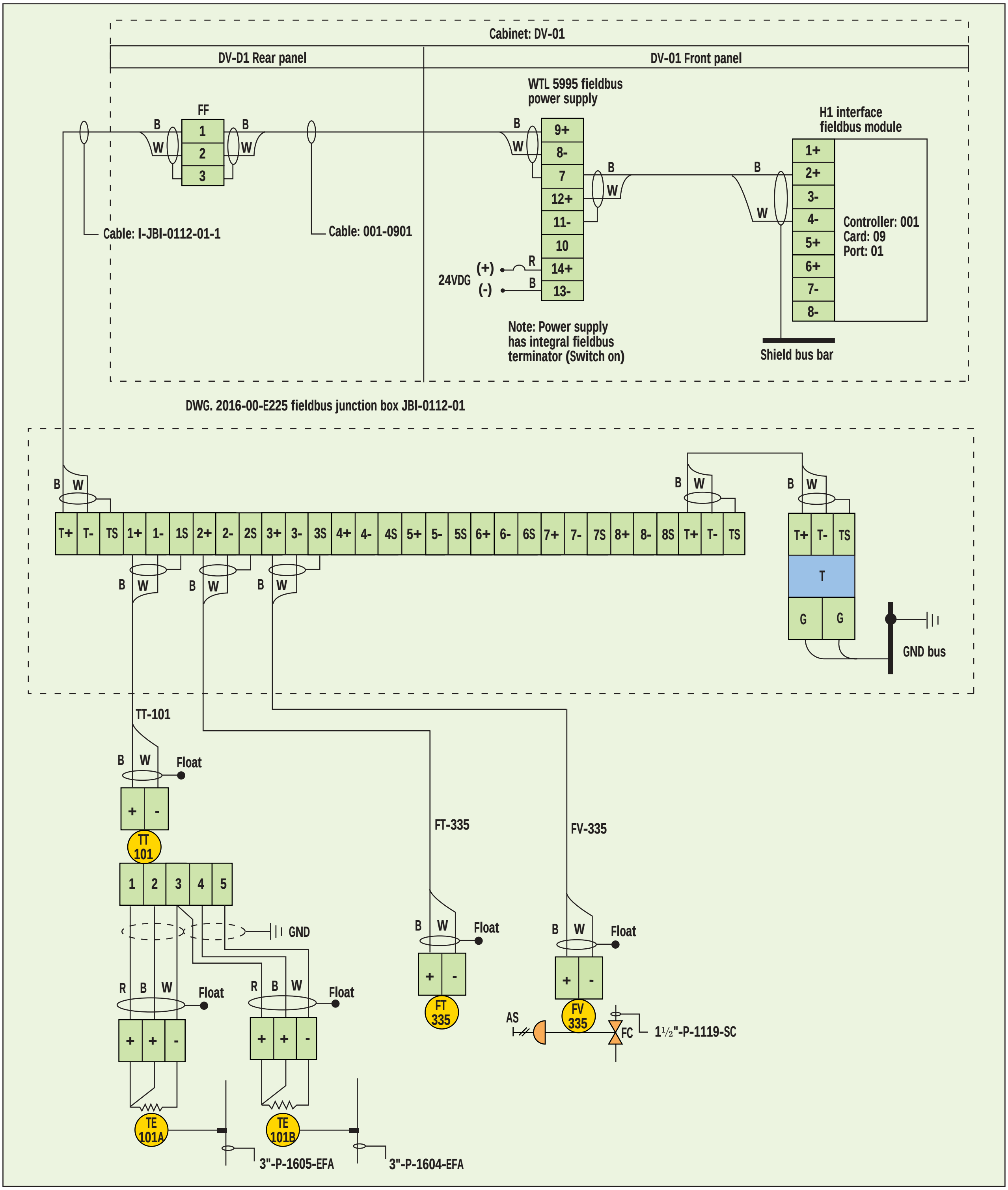
Instrument data sheets acquire added importance when designing for Foundation fieldbus. Not only must they include classical information, but also device description revisions, the function blocks supported by the device, fieldbus certification information, and the backup-link active scheduler. Replacing a device in the field not only requires that transducer type and limits be reviewed and compared, but that control functionality be reviewed and compared as well. For example, Figure 1 is a P&ID for a hypothetical reboiler on a distillation column. If a control strategy uses TT101’s input selector block, the replacement device must contain that functionality or the block must be moved and executed in another fieldbus device or perhaps in the control system’s native controller.

Loop diagrams are replaced by fieldbus segment diagrams. The old-style loop sheet included all essential electrical connection details from the control system to the instrument, including instrument power and grounding requirements, shielding treatment, terminal block connections, wire lists, and nomenclature. Segment drawings provide the same information, but for all devices on the segment.

Figure 2 shows the segment drawing for the hypothetical reboiler. Certain operating companies prefer their loop sheets show instrument types, calibration data, and software functionality. However, tools available today render this practice superfluous and a likely repository for superseded information. Our philosophy is to keep the segment drawing to electrical details only.

FIGURE 2.

USE SIMPLE SEGMENT DRAWINGS



FOUNDATION FIELDBUS SEGMENT DRAWING FOR THE HYPOTHETICAL REBOILER IN FIGURE 1. LIMITING THE SEGMENT DRAWING TO ELECTRICAL DETAILS HELPS AVOID MAKING IT A REPOSITORY FOR SUPERSEDED INFORMATION.

Documenting P&IDs Is Difficult

Many questions arise about how to treat P&IDs on a fieldbus project. For instance, should information be added to the drawings to reflect function blocks belonging to certain devices? Should additional symbols be added to an otherwise-ISA-standard document to distinguish fieldbus devices from analog devices? We concur with ISA that the purpose of a P&ID is not to document wiring techniques, distinguish electrical instrumentation, or present the location of control functionality. In the words of specification ISA-S5.1, "Additional details of the instrument are better described in a suitable…document intended for those requiring such details."

As far as the control system is concerned, the intent of a P&ID is to document instrument and control functionality belonging to a particular loop in an effort to describe the process and its equipment. Knowing whether a PID algorithm is performed by a transmitter, a valve controller, or in the control system itself does not help this effort. Showing the location of the PID algorithm opens the possibility for error and makes additional documentation updates necessary as changes occur.

Therefore, we make no changes to how the P&ID represents the process. Referring to Figure 1 again, note that the steam flow control to the reboiler is cascaded from a calculated average temperature from two process measurements of the process return lines to the column. To the operator and process engineer, this document includes all the information necessary to design and operate the process.

For an E&C company, this approach adds the benefit that Process Engineering can proceed without need for continuing (and changing) inputs from Controls Engineering. Questions as to how to show which instruments are on which segments, where the PID algorithm is being performed, and how to show multichannel and multivariable transmitters don't need to be addressed on the P&ID.

So Where Do You Show This Information?

Having determined that the P&ID is not the place to detail the PAS configuration, where should the details be documented? The answer is in the PAS's self-documenting capability. As an example, one modern control system is programmed in DeltaV Control Studio2 from Austin, Texas-based Fisher Rosemount. This tool is used to develop control strategies and determine where function blocks are executed (i.e., in the valve, transmitter, or controller).

When a function block is targeted to run in a device, the application self-documents the device name and physical location next to the block. When printed out, the configuration essentially becomes a control loop sheet. A screen dump of an IEC 61131.3 Function Block Diagram-language temperature-control loop (Figure 3) is used for documentation.

Whether blocks are run in devices, the controller, across controllers, or across bus protocols (Profibus-DP vs. Foundation fieldbus vs. HART), the software self-documents as it goes. If the control strategy is ever changed, say, if a PID is moved from the controller to a valve, the application automatically documents this move and can be printed for formal documentation. No change is required in P&IDs, loop drawings, or segment drawings.

System Design Is the Next Job

System design has two major tasks: assignment of devices to fieldbus segments and system configuration. As with a conventional DCS, each field device is assigned to a controller, usually by plant area. The designer who previously was responsible for the connection from the instrument to the junction box and back to a marshalling cabinet in the equipment room now must assign the instrument to a fieldbus segment.

Working with the controls engineer, the designer must ensure that the segment does not exceed physical and functional constraints. Points to consider:

- What is the device type and its associated limits?
- All components of the control strategy (transmitter, valve, and other loops involved in a cascade scheme) must be on the same segment.
- Trunk and spur cable lengths must be within limits.
- Voltage drop calculations must be performed for each segment.
- The required macrocycle time is within specified limits.
- At least one instrument has Backup Link Active Scheduler capability.
- The number of virtual communication references (VCRs) is not exceeded. (Each fieldbus device, including the control system, has a limited number of links.)
- The number of fieldbus function blocks is not exceeded. (The control system keeps an image of these blocks and has finite capabilities.)

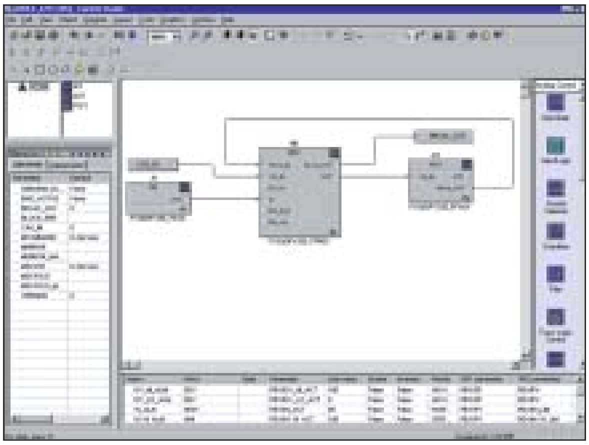
Optimizing segment design can take two or three iterations of this constraint-checking process. Just when you thought you were finished, a valve needs to be relocated and you have to start all over again!

Tree, daisy-chain, and crows-foot topologies are permitted with fieldbus segments. We suggest keeping it simple and familiar by using the tree topology, where all instruments have a spur connection to a centrally located junction box. Products are available for making connections to the fieldbus trunk. We chose a connection method incorporating a fieldbus terminator and multiple spur connections to the trunk.

The majority of fieldbus systems developed to date have been installed in small areas requiring two-dimensional layouts only. Many chemical plants are on multiple levels, of course, so 3-D plant design tools such as piping design and management systems (PDMSs) can assist segment layouts. At Kvaerner, we developed tools using a PDMS to assist in visualizing segments. The tools blend x-y-z coordinate information with instrument data to verify segment lengths and voltage drops. We have also developed design rules based on typical configurations. A red flag is raised if any functional constraint is approached.

FIGURE 3.

EASY DOCUMENTATION



FISHER-ROSEMOUNT SYSTEMS

CONFIGURATION SOFTWARE CAN EASE DOCUMENTATION. THIS SCREEN DUMP OF AN IEC 61131.3 FUNCTION BLOCK DIAGRAM-LANGUAGE TEMPERATURE LOOP CONFIGURATION ESSENTIALLY BECOMES A CONTROL LOOP SHEET.

Handling packaged equipment is the final frontier. Typically, an E&C company's scope includes compressors, boilers, dryers, and the like. We've had limited success with packaged equipment vendors in developing fieldbus segments for instrumentation they provide. Ideally, the vendor would provide all his fieldbus instrumentation prewired to a junction box and ready for a trunk to be connected. For a small package with one or two segments, fieldbus host software running on a laptop with a PCMCIA fieldbus interface can be used for checkout of the package.

Control System Configuration

Control system configuration is the application of system capabilities to the particular process. Configuring a conventional DCS requires the application of process knowledge together with process control and DCS expertise. Responsibility for configuration typically falls to one of the project's parties: the owner (especially if a propriety or sensitive process is involved), the E&C company, or the system vendor.

Process knowledge, and process control knowledge as well, are to a large extent conveyed down the design chain within P&IDs and associated specifications and descriptions. Process control and DCS expertise further derive from training and experience. The entity responsible for configuration will affect E&C company input and price. With the move away from DCS toward PAS, Foundation fieldbus instrumentation design becomes an intimate part of system configuration. This adds to the configuration workload. It also means that communications between the programmer, E&C designers, and vendor engineers must be solid.

Conclusion: It's Not Hard, Just Different

There are still some applications not filled by fieldbus instrumentation. Multivariable mass-flow transmitting is an example. We've additionally discovered it's easy to reach the functional limits of fieldbus during segment design. The available library of fieldbus function blocks is not extensive, for example, so some of our more complex control strategies had to be performed within controllers. The reason was not to meet basic control needs, but to provide for correct operation when changing modes, adding feedforward logic, etc.

Manufacturers are adding functionality to their devices to overcome these issues. Some newly developed function blocks will exploit multivariable and multichannel instrumentation (i.e., multichannel AI and DI), which will reduce some of our concerns. Wiring could be made even simpler if H1 cards were available with built-in power conditioners, so fieldbus segments could be landed directly on the terminals.

Kvaerner's first large-scale experience applying fieldbus has shown that the technology is ready for wide application. As a result of our experience, Kvaerner can now offer large-scale field-based automation engineering, procurement, and construction (EPC) solutions using the same efficiency tools deployed for traditional systems. We expect to provide valuable benefits to the field construction and commissioning crews and lifecycle benefits to end-user operations. Our forward objective is to offer proof of this as we complete the construction, commissioning, and start-up activities on this first major project.

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