POWER Engineering

Digital Bus Technology in New Coal-fired Plants

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The adoption of digital bus technology such as Foundation fieldbus, Profibus-DP or DeviceNet is a significant shift from traditional power plant instrumentation and control. Digital bus experience in a number of industries, including power plants, has shown that the technology performs solidly, can reduce initial capital costs, makes startups quicker and can save money on operations and maintenance once the plant begins operating. The biggest issues associated with including digital bus technology in a new power plant are deciding on which systems to install the digital technology and determining how to implement it.

Traditionally, distributed control systems (DCS) have been proprietary and on a 15- to 20-year renewal cycle. With the adoption of personal computer type technology that cycle has been reduced to three to five years. Evolution in networking, fieldbus and control technologies has also followed a version of the computer world's Moore's Law where more is achieved with less at the same cost.

Examples abound in the instrumentation arena where sensor devices provided only single process values and were connected to the control system through a single set of wires. Today's advanced devices can perform continual diagnostics and provide much more information than just a single process value. Further, many of these devices are now able to use and exchange this data and provide controls execution capabilities using digital bus technologies such as Foundation fieldbus.

Smart devices have existed for more than 15 years using the HART protocol, which superimposes a digital signal on top of a standard 4-20mA signal. Many utilities adopted these devices because they are cost competitive with conventional devices and can directly replace (one-to-one) existing devices with no required rewiring.

Digital bus standards such as Foundation fieldbus, Profibus DP and DeviceNet (where all the communication is in digital format) in some cases offer additional functionality over the original smart instrument devices. Direct fieldbus interfaces in the control systems provide users with access to abundant data. Asset management software packages use this data to provide detailed diagnostic information and predictive maintenance analysis functions. Control accuracy is also improved because the signals are not converted to 4-20mA for transmission to the DCS input/output (I/O) module then converted back into a digital value for use in the control scheme.

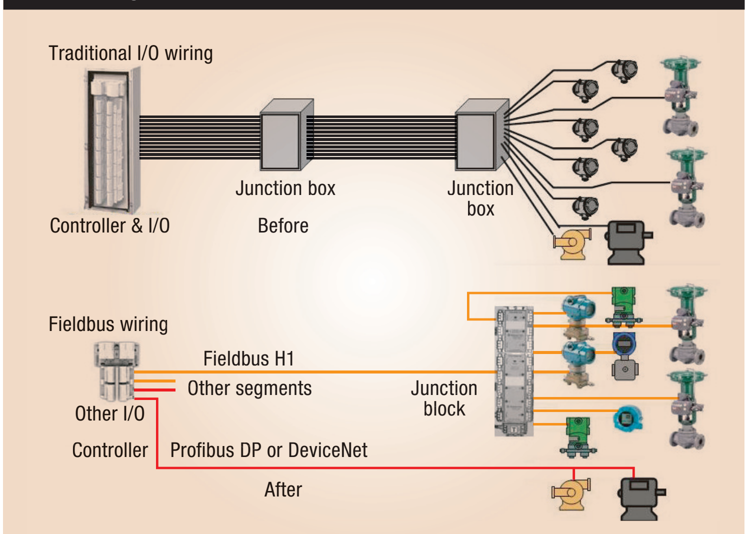
In addition to providing primary sensed values, smart instrumentation and actuators are rich sources of other data, both on themselves and the process.

Control System Changes

While digital bus technologies, such as Foundation and DeviceNet, in the control system change some things, many features remain the same. Digital bus technologies do not alter the basic control design, graphics, database and the control system's main architecture. Nor do they significantly change the design documentation philosophy. Human interfaces for engineering, business, maintenance, performance, historian and other systems functions also remain unchanged. So does the engineering process used to segregate I/O signals, controls and processes.

Digital bus technologies do, however, change the structure of the connection with the I/O. Instead of dedicated wiring from each field device to the DCS I/O, the bus architecture allows a single cable to connect a number of digital devices. The interface to the I/O represented by the devices is changed to a digital fieldbus module (Figure 1).

Figure 1 TRADITIONAL VS. FIELD BUS WIRING



The simplest analogy is that the traditional I/O channel has been placed out in the device and the I/O bus used to read the channels is now a fieldbus cable instead of a backplane. This cable, with its multiple data points, significantly reduces the number of wiring pulls and cable trays in the plant. The documentation and its upkeep are also reduced.

The I/O module space required in the controller for one or more digital bus interface modules is significantly reduced over that needed for the traditional I/O modules and terminations. Foundation fieldbus uses shielded twisted pair wiring (STP) carrying power and data on the same pair of wires while DeviceNet uses four wires with the data and power separated. This may require some additional space for fieldbus device power supplies, distribution modules and power conditioners.

Designing the DCS with digital bus technology in mind and using integrated configuration and asset management software is important. The design should support conventional HART, analog I/O, discrete I/O and special purpose I/O required due to speed, time resolution and/or safety requirements. In addition, it should support multiple fieldbus types. These include Foundation fieldbus, used primarily for analog control, and DeviceNet or Profibus DP, used more for discrete control applications. In some cases, the required devices' capabilities will dictate the use of multiple digital bus types.

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TABLE 1 PORT WESTWARD FOUNDATION FIELDBUS DEVICES USED

Manufacturer	Device Type	Model/Description	Quantity
Rosemount	Sensor device	3051 and 3095MV transmitters	118
Endress & Hauser	Sensor device	FMR 240 radar level transmitters	2
Rosemount	Sensor device	848T 8 x T/C transmitters	28
Magnetrol	Sensor device	Eclipse 705-52 radar level transmitters	3
Fisher	Valve positioners	DVC 6000F, 6010F and 6020F	9
Masoneilan	Valves with positioners	Sipart PS2	14
Copes Vulcan	Valves with positioners	Sipart PS2	13

New Plant Implementation

New coal plant construction is one of the most cost-effective opportunities for implementing digital bus technology and automated intelligence. For example, one new subcritical coal-fired plant in the Midwest (scheduled to begin commercial operation in 2009) is installing Emerson Process Management's Ovation Expert Control System for all significant plant control functions. The Ovation system is interfaced to the turbine control system using an OPC interface and to an FGD PLC control system using Allen-Bradley Ethernet protocol. Digital bus technology is incorporated into as many areas as possible. Both Foundation fieldbus and Profibus are used significantly throughout.

In addition to coal-fired power plants, combustion turbine and combined-cycle power plants can also benefit by incorporating digital bus technology. An example of this is Portland General Electric's new 407MW Port Westward combined-cycle plannt that recently entered commercial operation in economic dispatch mode. It also uses the Ovation control system with bus technology extensively for the heat recovery steam generator (HRSG), balance of plant (BOP) and electrical subsystems. The combustion and steam turbine controls are interfaced using Modbus/TCP.

Every significant valve in these new plants is a Foundation fieldbus device (Table 1). The devices are applied to most significant control functions, including feedwater, drum level, spray valves, turbine bypass and most analog instrumentation. Thermocouples are used in both plants and are landed on either traditional TC I/O modules or on Foundation fieldbus modules. Profibus-DP is used for all motor operated valves as well as switchgear and motor control center (MCC) equipment (Table 2).

Vendors such as Rockwell and Siemens natively support DeviceNet and Profibus-DP, while other vendors have their own original communications interface implementation for which they provide adapters to convert to the required digital bus technology. A better approach would be to use their native interfaces if supported by the control system rather than insisting on a single bus type.

Factory Acceptance Tests

In the recent past, the DCS control schemes' factory acceptance tests (FATs) simulated the plant devices by hardwiring 4-20mA power supplies, meters, lights and switches to the DCS I/O. FATs were done this way because of the impracticality of having all the field devices (particularly the larger ones like MCCs) available for testing. More recently, it has become commonly accepted practice to inject software simulated signals at the I/O bus level instead of at the field signal side. This is in part due to the greater familiarity with software simulation technology. The field practice still requires installing the actual DCS in the plant to connect, individually test, calibrate and commission the devices. This simple practice is well understood and accepted. However, to confirm the connectivity between the control system and the devices on a channel-by-channel basis, the process is lengthy and highly manpower intensive.

Because of the use of busses and their integration into skids and equipment lineups, it is impractical to have all the smart devices available for DCS factory testing. A process that has worked well on a number of projects, however, is to test one representative device for each device type in the plant. This provides the designer with proof of concept, allows the control system supplier to confirm operation with the control logic and reassures the owner that the connectivity using the correct drivers is viable throughout the chain from the HMI through the bus interface to representative devices.

Original equipment manufacturers can select devices with varying capabilities from many device vendors; therefore, it is preferable for these devices to be certified by the respective digital bus foundations whose functions are to ensure interoperability. However, the need exists to test the equipment vendor's complete packaged system, such as an MCC or switchgear lineup, by using the digital bus host and configuration PC package connected via the actual trunk and spur cabling to the devices as configured for the plant. This ensures the supplied system is capable of interfacing, communicating, monitoring and controlling the process within the response times required.

Neither of these tests conducted alone proves the complete communications chain. However, in combination they assure that the significant elements can communicate successfully and provide the digital bus benefit of quick and easy field commissioning. Many in the industry expect that once power industry personnel become familiar with digital busses, the FAT tests will resort back to software simulation of the signals available combined with DCS vendor standard device connectivity tests through the digital bus interfaces.

Asset Management Software

The biggest advantage of asset management software is that it provides a single location for device configuration, calibration management, diagnostics and in-plant smart device documentation. The commissioning process allows configuration to be conducted through graphics on-screen interface with the devices. Field personnel are needed only to verify that the correct process device is being read or manipulated and that the valve stroke and feedback mechanism is correctly adjusted on actuators. Calibration documentation and an adjustments audit trail, including what was performed and by whom, are preserved for future reference.

To realize the full capabilities from the smart devices, a DCS system using Foundation fieldbus should be supplied with management and diagnostic software. Emerson's Ovation DCS system requires its Asset Management System package (AMS Suite) for this purpose. Any asset management software tool should include support for at least a minimum number of device tags. The packaged number of device tags should be adjusted to include the most important and critical devices. With any management software, it is important to understand how many tags have been

TABLE 2 PORT WESTWARD PROFIBUS DEVICES USED

Manufacturer	Device Type	Model/Description
Auma	MOV	Aumamatic AM 01.1 MOV with Variomatic VM
Limitorque	MOV	Accutronix MX (FCD LMA1M 1336-00)
GE Multilin	MCC/Switchgear	P485 Modbus to Profibus interface Connected with Multilin switchgear devices 469 motor management relays
Schneider Square D	MCC/Switchgear	Momentum I/O (170DNT11000)
VersaMax	MCC/Switchgear	Network interface unit I/O device

**Approximately 100 total devices*

supplied and to determine if this number is sufficient for the project.

Optional add-on packages are available that extend and broaden each manufacturer's device diagnostic and analysis capability. These should be reviewed and specified to be included in the asset management and diagnostic software package.

Asset management software's real value is its operations and maintenance savings ability. Foundation fieldbus devices have three levels of internal diagnostic alerts: failed, advisory and information. Each alert type can have multiple contributor items. These alerts should be integrated into the control system, with filtering based on device criticality, to predict a device's issues and failures. In addition, maintenance personnel can have full and detailed access to the predictive diagnostic data to observe, plan and schedule any repairs or parts necessary to remove the alert. The changes to maintenance work practices mean that personnel service, with previously identified parts and repairs, only those devices that need service thereby minimizing repair time.

Installation and Work Practices

Some digital bus technology benefits include reductions in cable trays, conduit and cables. This greatly simplifies the associated field installation design. The reduction in I/O modules reduces their cost, the associated cabinet cost and also results in fewer field terminations.

Other cabling benefits can be achieved by using prefabricated cables and segment junction blocks with trunk cabling and short circuit-protected spur connections. These can provide spare device connection points and allow device removal without affecting the complete segment.

Owners who choose to use digital bus technology are not required to adopt it for all applications. It can be readily mixed with conventional I/O. However, the use of bus technology blurs the lines between traditional DCS functions and the smart instrumentations' functions, because both can execute control strategies. This may not be a major issue, however, because the control design does not have to change; it can still be executed in the controller.

Although Foundation fieldbus can provide control-in-the-field (CIF) function, most owners are not yet ready to implement these capabilities as they are just becoming familiar with digital bus-based technology. So far, implementations have used the backup Link Active Scheduler but not the PID capabilities of some devices. Once Foundation bus technology is selected, however, the CIF option is available should the user need or want to try it.

The need to segment functions, loops, equipment, I/O and processes does not change whether or not bus technologies are selected. Segmentation remains necessary to ensure the process remains safe and continues to run in the event of disruptions caused by process, instrumentation and other failures.

With conventional I/O, the numbers of each I/O type are determined by reviewing the plant's piping and instrumentation diagrams. Fieldbus control strategy design requires the same basic I/O types and information. There may be some additional control strategy permissives required that allow remote operation via the fieldbus.

Smart instrumentation requires careful device selection from the respective foundation's approved vendor lists to avoid incompatibilities and possible field commissioning issues. Smart devices also have variable I/O, data transmission, diagnostic, on-board process control function blocks and logic processing options. These capabilities' impacts must be understood and considered during control strategy design. The devices need to be purchased with the appropriate options available.

Care also should be taken to understand the function blocks' operation. Does the device execute a select function block between two transmitters and provide one input to the PID function block? Is the device capable of providing a backup Link Active Scheduler function to run the loop in the event of controller or fieldbus interface module failures? These issues need to be reflected in the devices' and the control schemes' instrumentation data sheets.

However, different I/O configurations in which the devices can communicate on the bus may exist. One configuration should be selected based on one of three perspectives: What I/O is really needed for the device's control (the basics)? What I/O can be made available, if needed, for process and device diagnostics and alerts? What other data is available to an analysis function that provides the advanced diagnostic capabilities? This prioritizes the data and the required access to it. These should be clearly identified and, where possible, standardized for each device type so that some repeatability of configuration and control scheme interface can be maintained. Once defined in the design process, all vendors need to maintain the standard.

Foundation fieldbus devices can execute control functions in the field through flexible function blocks and so have the necessary control status data exchanges built in. Some Profibus and DeviceNet devices have device specific internal logic capabilities, some based on 61131-3 programming. Any control being considered for implementation on the device needs to be designed within the overall control scheme early on so that all parties understand the interfacing, status and I/O update requirements this may impose between the control capabilities.

Field Practices

Some vendors supply Foundation fieldbus segment design tools that provide a graphical means for cable selection, specifying cable distances along with the interconnect components such as host interfaces, power conditioners, connection blocks and devices from a library. The available information includes the components' power usage and other relevant parameters. The design results tend to be conservative, which works to the designer's advantage to prevent overruns. However, segment design should allow for future spare requirements and not attempt to maximize the segments loading.

The field effort involved with commissioning devices on a segment-only basis requires the correct devices to be identified, along with their correct junction block connections. This can be accomplished by successively disconnecting the device and its cabling in the field and observing the effect at the system consoles that display the device's asset management information. Once that has been accomplished, all remaining commissioning work can be carried out by a single person in the central control room using the DCS console screens.

Actual segment cable routing is sometimes left to the discretion of the CAD drafter or the site contractor electrician, who have information only on device placement and junction boxes specified. It is likely that neither the drafter nor the electrician is aware of how exceeding distance limits or improperly routed cable can impact digital bus technology. In one case, lack of digital bus understanding resulted in an out and back segment wiring layout which appeared to meet the distance limits but did not function properly. Communications with one of the more distant devices were lost and when reviewed, personnel found that the bus cable had been zigzag routed in installed cable trays, causing the distance limit to be exceeded. This illustrates why designers and suppliers should not assume all personnel have the same digital bus technology knowledge.

Installation personnel should have a general knowledge of what digital bus segments are, what components they consists of, how to identify the correct cabling and connectors, what routing considerations may affect operation, what tests should be preformed, and how those tests should be conducted. It is best to assume that some basic digital bus technology training will be required by all personnel involved in its design, selection, installation and use.

Segment wiring checks are important because a single pair of wires connects a number of devices and in the case of Foundation fieldbus can also provide device powering. Each segment, including the wiring polarity, the voltage at the device, the actual signal waveform and the device's communications function should be checked with an appropriate hand calibrator, multimeter, etc.

Other digital busses separate the data from the power wiring. Profibus-DP assumes a completely separate field device power wiring scheme. DeviceNet takes a slightly different approach in that the standard cable includes a separate pair of wires for device power. However, both are specific in their wiring and powering recommendations, therefore, testing and measurements should be an inherent first step in any commissioning process. The reliability and integrity of the data transmission between the field devices and the controls are only as good as the interconnecting wiring, so better wiring quality will garner better results. In the end, more than one signal will be affected by poor quality cabling and connections.

Junction blocks with additional capabilities are also recommended. These include identified trunk and spur connections, short circuit protection on the spurs and switchable terminators. All fieldbus technologies require termination of both ends of the trunk cabling to eliminate reflections and ensure communications. Spur short circuit protection prevents an incorrectly wired device from affecting the other devices and interrupting the segment communications.

Digital bus technology in power plants is still new and it will take the power generation industry some time to use it proficiently. Nevertheless, digital bus experiences to date have shown that the technology performs solidly and when wiring and connections are correctly made and wiring best practices are followed, a significantly shorter commissioning cycle can be achieved. pe

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