Controlling Processes via Fieldbus

Increasing reliability and reducing costs

By John Rezabek

A proprietary digital bus and smart instruments can limit chemical process design flexibility and inflate expansion, modification and life-cycle costs. FOUNDATION fieldbus provides a wide selection of optimum or best-in-class field devices. Fieldbus also offers more features than do "smart" instruments and the digital communications of older distributed control system (DCS) technologies.

To automate the first large-scale manufacture of 1,4-butanediol (BDO), BP Chemicals, Lima, Ohio, selected a powerful field-based control architecture based on FOUNDATION fieldbus.

The new plant produces BDO directly from butane in a process jointly developed by BP Chemicals and Lurgi Oel-Gas Chemie, Frankfurt, Germany.

Reliability challenges

With a traditional DCS, reliability is maximized through redundancy in input/output (I/O), wiring, power supplies, controllers and other areas. A DCS concentrates too much logic in the controllers. Dozens or even hundreds of loops are solved by a single processor.[*] Pre-DCS panels of single-loop controllers actually made for a more distributed architecture.

Centralizing DCS logic in a rack room and fanning out hundreds of cables to 4-20mA field devices creates vulnerabilities in the control system. Without redundancy, a single failure can bring down the entire control system. FOUNDATION fieldbus creates a path for achieving high reliability with fewer components and less complexity, cost and redundancy.

When redundancy is redundant

During BP Chemicals' failure-modes-and-effects analysis, plant engineers

A bank of fieldbus control and I/O modules, shown here, offers fully distributed logic.

studied the failures possible with various devices. A fieldbus control valve, for example, has few failure modes: 1) the fieldbus cable is severed, shorted or opened, 2) the fieldbus card's power conditioner fails or 3) the valve fails. The last mode is irrelevant because the problem and solution are identical in both fieldbus and DCS architectures.

System reliability can be maximized by taking the PID logic out of the process controller and distributing it to the fieldbus valve controller. If the transmitter is on the same segment, or fieldbus H1 network, the entire loop is solved in the field. If the valve controller and the transmitter are powered externally, the failure of host components causes loss of view only.

With fully distributed logic, the process also proceeds under full variable control, which often is superior to proceeding "as last instructed." This is not good enough in the BDO plant because many vessels have short residence times or rapid changeover. Loss of variable valve control requires a heroic effort on the part of operators to avoid an upset or a shutdown. Depending on where the failure of the fieldbus segment occurs, cascade control also will proceed normally if the cascade masters and slaves are distributed to the field as well.

BP's failure analysis also indicated that a highly logic-distributed, fieldbus-connected, essentially nonredundant automation system could provide reliability equivalent to a highly fault-tolerant DCS. BP then had to ensure high reliability was established in the field.

In 1998 and 1999, when designing the BDO system, the most worrisome elements of the field-based automation system were the H1 segment power conditioners and the physical segment wiring. BP had no reason to believe H1

[*]Controller outputs are computed based on inputs using the control algorithms, e.g., proportional-integral-derivative (PID).

card failures would be epidemic, but knew the card was the only component of the automation system that had not experienced several years of operating service in large numbers of installations. At the time, the automation system did not offer redundant H1 cards. However, BP determined that an operator could handle a temporary loss of view, diagnose the failed card and replace it in an hour or less.

Spreading risk

BP saw no need to establish redundant segment pairs. Single-pair fieldbus home-run cables lie in overhead cable trays in pipe racks. Drops to junction boxes — and from junction boxes to devices — are in rigid conduit. A radial topography for the 71 segments was selected, with an average of five or six devices per segment. Some critical segments have as few as two devices.

Radial topography and low segment loading were other conscious choices to ensure reliability. BP classified every field device by one of three levels of criticality. The most critical — plus those requiring the fastest response — reside on the least-loaded segments.

After gaining experience with the new automation system, BP felt comfortable switching to a hybrid multidrop fieldbus topology for a process revision underway. Instead of running new conduit to the top of a reactor, the company stubbed into an existing instrument, added a junction box, made the box the termination of the fieldbus home run and then wired to the new instruments.

The fastest macrocycle available in the fieldbus implementation is 250 microseconds (mS). The most demanding in terms of response time are fieldbus devices in several compressor antisurge controls. A large number of function blocks must be solved; therefore, these controls run at a 500-mS cycle and do not follow the surge curve as closely as they might with a very high-speed processor.

Landing fieldbus leads

The BP fieldbus installation included a hermetically sealed manual disconnect switch in the spur to every device, plus a weatherproof circular connector on the

fieldbus pigtail cord landing every pair. Rigorous wiring was employed for two reasons. First, the connectors would help prevent inadvertent shorting during maintenance. Second, they would reinforce the idea that fieldbus should not be handled casually. Since the introduction of short-circuit protectors for fieldbus spurs, BP has reverted to traditional terminations on all new devices.

BP conservatively placed all cascade masters in the automation system's scalable controllers instead of on the fieldbus segments. The master's process variable (PV) resides on a separate segment, so if one segment fails, BP would not lose both primary and slave PV indications. If the company were to design the BDO plant again, it would probably place both masters and slaves on the same segment because fieldbus H1 communications now are proving durable and reliable. Also, with cascade control removed from the process controller, reliability would improve because data interchange between cascaded devices would be closer to the process.

The only 4-20mA in the new BDO process is for large compressor blowoff valve actuators, large double-acting sliding-stem valve positioners and local PV indicators at control valve bypasses.

Single process control platform

A programmable logic controller (PLC) was not selected to handle the BDO process's 400 nonemergency shutdown (ESD) discrete points, avoiding a third platform beyond the process automation and the ESD systems. The discrete points are hardwired to process controller I/O modules.

All five of the automation's dual-redundant process controllers are located in a single cabinet in an equipment room adjacent to the control room. Because the BDO plant is less than 500 meters long, end-to-end, operators were not motivated to distribute controllers to the field. The controllers and the control console's seven sets of dual-monitor PC operator stations, as well as the plant's engineering and application workstations, are networked on IEEE 802.3 Ethernet.

An RS232C serial link allows the

ESD system to publish data to the automation system via Modbus. Unfortunately, too much BDO project engineering time was spent mapping the ESD system to the automation system. Future projects requiring an ESD will employ an OLE for process control (OPC)/Ethernet link.

Easy configuration

In a joint effort, BP Chemicals and an engineering consultant configured the automation system in International Electrotechnical Commission (IEC) 61131.3 Function Block Diagram (FBD) and Sequential Function Chart (SFC) languages. Pre-engineered function blocks such as PID include all necessary logic.

With fieldbus function blocks, control engineers need not program status bits to perform certain functions — they are ready right out of the box. The PID block, for example, looks at both the measured variable and its status. Fieldbus has more than 80 different designations, allowing the programmers to customize controller actions to particular PID inputs.

If, for example, the status is "good noncascade" and an electronics problem arises, the fieldbus device changes its status and the PID block adjusts its mode appropriately, perhaps switching to manual mode. Or if an impulse line becomes plugged, the transmitter changes signal quality status from "good noncascade" to "uncertain." This flags the operator that he might have a plugged line.

Mode shedding is transparent and permits graceful degradation of control. Graceful degradation is of great value in the BDO plant because it reduces process upsets caused by instrument malfunctions. The PID block also knows if the valve is limited — at one of the extremes of its mechanical travel — and cascade masters know if their slave's valve are limited. No special programming is required for antireset windup or bumpless transfer.

Beyond diagnostics, BP currently is not taking advantage of the data that can be extracted from fieldbus devices. However, one node on the automation network is a process data server built into the automation system. A server-to-server link allows a larger historic data server on the site's information technology (IT) network to upload process data from the automation's server so customers can view recent process information.

Many operator benefits

BDO plant operators now can see control valve positions on their displays. Every faceplate and valve icon indicate true position with every scan, which is extremely helpful when balancing flows during startup. Visible valve motion also informs the operator of the presence of a poorly tuned or sluggish valve.

Most instrument boxes incorporate heaters to stave off cold weather problems. Instrument case temperatures are brought back to a special display so operators can watch for impending freezeups or for devices being heated with steam hose. Transmitters in vapor service are kept warmer than others, and the difference can be monitored.

All Coriolis mass flowmeter readings include calculated density, which informs operators which material is flowing and its concentration. Specific gravity is especially helpful in determining the demarcation between process water and an acid, for example.

BP was able to commission fieldbus devices extremely quickly because the devices reported themselves to the automation system as soon as their wires were landed, or fastened to their permanent wiring terminals. Information typically stored in a device data sheet became available immediately. All valves were calibrated in place, and all instruments relied on the manufacturers' certified calibrations. A calibration trailer was not necessary during construction, saving money and time.

Future directions

BP plans to make extensive use of the information available from FOUNDATION fieldbus devices to develop expert-systems operator advisories. The company probably will program into logic the combined intelligence and experience of its engineers, operators and maintenance personnel to speed troubleshooting and problem-solving and provide the best solutions.

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A termination of a fieldbus spur on a digital valve controller takes the PID logic out of the process controller.