Intrinsically safe fieldbus for hydrocarbon processing plants

The key issue is delivering enough power to a large number of field devices

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For about the past 30 years, it has been a "given" within the oil and gas industry that intrinsic safety (IS) is the natural technique for explosion protection of electronic instrumentation in hazardous locations. IS design permits instruments to be opened and adjusted under power, and electronic designers can make conventional two-wire 4-20 mA units intrinsically safe without too much difficulty. On the other hand, fieldbus users now want complex processing and digital communications to and from many devices interconnected in the plant. High power and multiple connections are major issues for intrinsically safe designs, so IS fieldbus has become a particularly aggravating problem.

The primary driver for making the design compromises necessary for IS was the requirement for "live maintenance"—the ability to open an instrument or junction box under power and make adjustments in the field. However, fieldbus devices don't have to be opened for physical adjustments since all such tweaks and settings are accessible through the network from engineering workstations and laptops. One could take the view that IS is no longer as important in fieldbus implementations as it is for conventional 4-20 mA systems. However, many users still seem to feel that the additional safety factors built into IS design make the pain of specifying IS segments worthwhile.

Fieldbus in hydrocarbon processing. Fieldbus technology allows multiple instruments (devices) to communicate with a control system on one twisted-wire pair or segment (Fig. 1), thus eliminating the need for massive and expensive "home-run wiring." Smart fieldbus instruments also simplify maintenance, diagnostics, tuning and calibration. According to ARC Research, major hydrocarbon processing companies such as Shell, BP, Chevron and others now specify fieldbus as their preferred technology as a result of well-identified and significant OPEX/CAPEX savings in multiple projects across the world. In fact, the hydrocarbon processing industry was the biggest supporter of fieldbus from the beginning, and continues to be the largest user of fieldbus equipment.

Unlike analog and HART-based systems, fieldbus is fully digital and supports fast, deterministic (time-stamped) communications. This eliminates signal degradation through repeated receive/transmit operations. The fieldbus devices themselves use more advanced processors, thus offering much more complex data and self-diagnostics. Having multiple devices connected onto one wire pair or segment saves cost, time and weight, all being important parameters in offshore systems design. Fieldbus is also an open international protocol; that is, devices from manufacturer A can still communicate digitally with control system B without requiring special software.

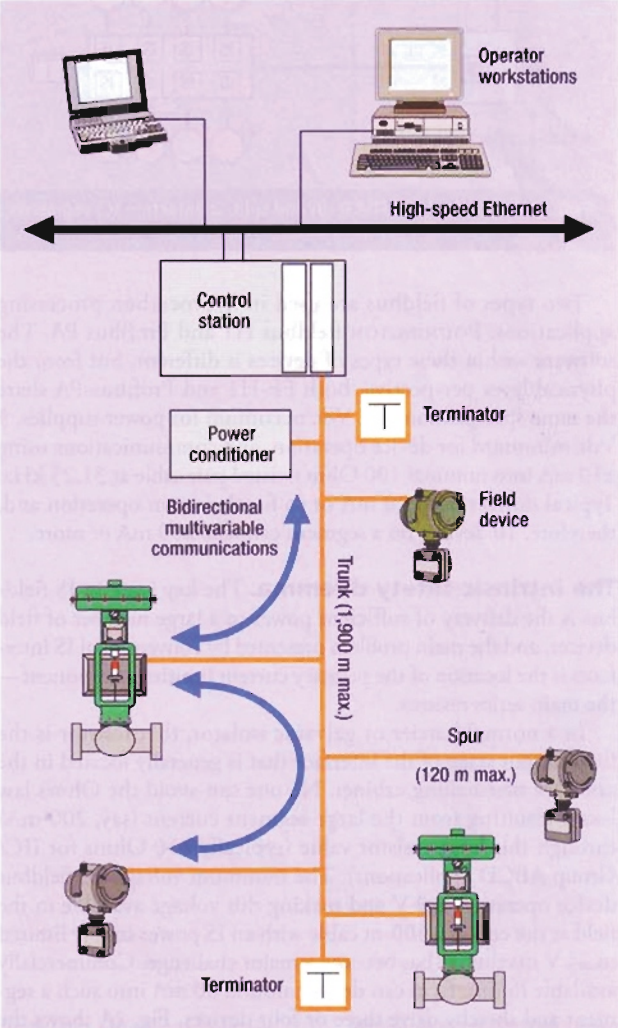

FIG. 1 Fieldbus technology allows multiple instruments to communicate with a control system on one twisted-pair wire or segment.

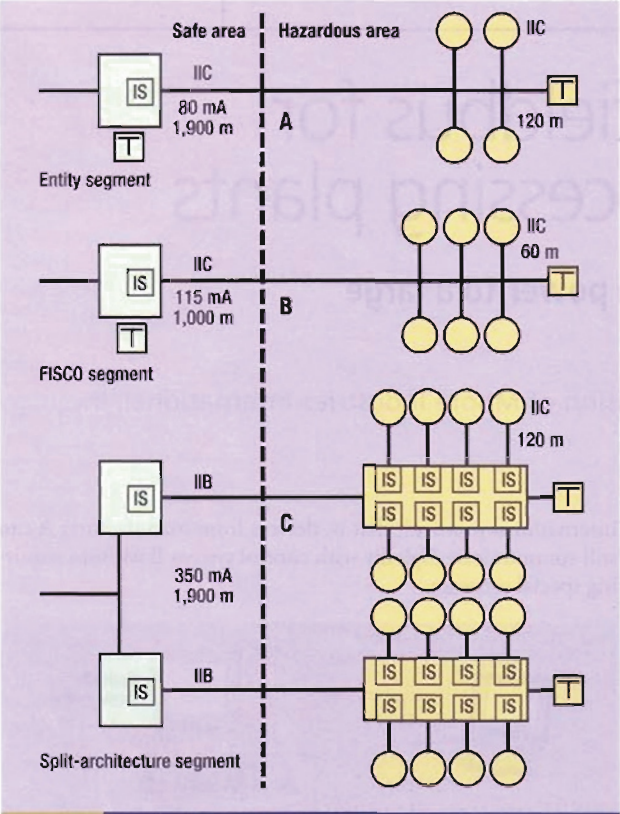

FIG. 2 Standard (A), FISCO (B) and split-architecture (C) segments.

FIG. 3 In this split-architecture system, the power supplies in the top rack are mounted in a safe area and supply power to the fieldbus devices in the hazardous area (photo courtesy of Boehringer Ingelheim Chemicals).

Two types of fieldbus are used in hydrocarbon processing applications: FOUNDATION fieldbus H1 and Profibus PA. The software within these types of devices is different, but from the physical layer perspective, both FF-H1 and Profibus-PA share the same specifications: 32 Vdc maximum for power supplies, 9 Vdc minimum for device operation, and communications using ±10 mA into nominal 100 Ohm twisted pair cable at 31.25 kHz. Typical devices need 20 mA or so for their own operation and, therefore, 10 devices on a segment can take 200 mA or more.

The intrinsic safety dilemma. The key issue in IS fieldbus is the delivery of sufficient power to a large number of field devices, and the main problem presented by conventional IS interfaces is the location of the primary current limiting component—the main series resistor.

In a normal barrier or galvanic isolator, that resistor is the final output stage of the interface that is generally located in the safe-area marshalling cabinet. No one can avoid the Ohm's law losses resulting from the large segment current (say, 200 mA) through this large resistor value (typically 110 Ohms for IIC/Group ABCD applications). The minimum voltage for fieldbus device operation is 9 V and making this voltage available in the field at the end of a 500-m cable with an IS power supply limited to 24 V maximum has become a major challenge. Commercially available IS interfaces can deliver around 80 mA into such a segment and thereby drive three or four devices. Fig. 2A shows the standard IS segment configuration.

Concerned over the limitations of conventional intrinsically safe fieldbus, engineers at PTB (Germany) developed a technique known as Fieldbus Intrinsically Safe Concept (FISCO), whereby they established experimentally that a nonlinear current-limited power supply could be used to extend the allowable current and, hence, effectively drive more devices in a hazardous area. FISCO power supplies are available that can deliver 110 mA into IIC/Group A/B-rated hazardous areas driving, say, six devices. Fig. 2B shows a FISCO segment configuration.

If hydrocarbon processing users can be persuaded to move away from their traditional bias for IIC/Group A/B/C/D devices, then it is possible to get FISCO IIB-rated power supplies that are able to drive 250 mA and, hence, drive 10 devices.

FISCO incorporates some restrictions that have been known to pose problems. FISCO works only if diversity and variance are controlled by restricting the device types and the cable that can be used. FISCO segments can be built using any device and cable, so long as they conform to FISCO standards.

Another problem is that FISCO segments can only support 1,000 m of cable (standard fieldbus segments can be 1,900 m) and the individual spurs cannot be longer than 60 m (standard fieldbus spurs can be 120 m).

The biggest problem, however, is that the MTBF of the segment is dramatically impaired over a standard segment configuration. The FISCO power supply is a complex electronic design and the weakest component parts are in series and cannot be placed in parallel. There is no redundancy in a FISCO segment and the reduction in MTBF is probably on the order of 10^2 or 10^3.

A different type of solution is available that approaches the IS current-limiting problem from another angle. Simply put, if the location of the current-limiting resistor is a problem, why not

TABLE 1. Comparison of IS segment design types

	Entity	FISCO	Split-architecture
Control drawing	Required	List of devices only	Required
Entity calculations	Required	Not required	Required (done once for the worst-case scenario; longest spur per type of cable specified)
Maximum current	80 mA	120 mA (IIC, Group AB) 265 mA (IIB, Group CD)	350 mA
Redundant design	No	No	Yes
MTBF comparison	Medium	Low	Very high
Maximum devices (20 mA per device and no losses)	4	6 (IIC, Group AB) 12 (IIB, Group CD)	16
Maximum segment length	1,900 m	1,000 m (IIC, Group AB) 1,900 m (IIB, Group CD)	1,900 m
Maximum spur length	120 m	60 m	120 m
Allowable area classification implementation	All zones and divisions	All zones and divisions	All zones and divisions
Hot work permit required to maintain/troubleshoot while energized	No	No	No

move it? This approach is known as split-architecture and the implementation most commonly used has an IS power supply with a relatively low-value current-limiting resistor rated for IIB. The power supply connects to a field device coupler where the individual spurs have additional current-limiting resistors, giving an output rating for IIC. This configuration provides for a segment current of 350 mA; i.e., the same level of current as in a conventional non-IS segment.

By using the standard IS interface as the design basis, the split-architecture approach can easily implement power supply redundancy and, because the standard IS interface is a very simple design, its MTBF can be demonstrated as very large indeed. A further advantage is that the split-architecture design is not limited in cable length in the same way as FISCO systems, allowing designers to use the full 1,900-m trunk and 120-m spurs in the same way as in a conventional non-IS segment. Fig. 2C shows the split-architecture configuration.

FISCO system promoters claim one significant advantage over so-called "Entity" systems: FISCO systems can only comprise all FISCO-approved components and devices; when so constructed, there is no requirement to undertake any Entity calculations. "Entity calculations" serve to demonstrate and document the safety of the segment design; i.e., that the power source output parameters and the device input parameters, plus the parameters due to connecting cable, are all within the limits defined by the hazardous location and the external approval authority (BASEEFA, FM, SIRA, etc.). FISCO implementations still have to demonstrate compliance with the safety approvals and that is usually achieved through a simple listing of the components used to build each segment.

For normal IS interfaces in nonfieldbus applications, this can be a great deal of work, since a process plant may have 50 types of barriers/isolators, 100 types of field instruments, and a variety of cable types and lengths (not surprisingly, IS interface companies don't make much mention of these calculations when they are selling nonfieldbus systems).

Again, the split-architecture design neatly side-steps this issue because each spur is considered a separate IS cable and each field device must meet one of only two sets of parameters (FISCO or Entity). Since the spur can have a maximum of 120-m cable length and real fieldbus systems use only one type of cable per plant, there are in reality only two calculations to make for the entire plant: one for an Entity device and one for a FISCO device, both using 120 m of cable. This also means that adding new devices is also easily permissible, since any new spur cannot exceed the parameters already calculated and documented.

Bringing FISCO and Entity IS systems together. In previous implementations, the split-architecture design has been based on device Entity parameters of 24 V, 250 mA and 1.2 W (values that the IS power supply must guarantee not to exceed and which are specified in IEC61158-2 and associated documents). FISCO devices, on the other hand, are associated with Entity values of 17.5 V, 380 mA and 3.8 W, so it has not been possible for Entity systems to easily demonstrate compatibility and safety with FISCO devices. This had become an issue with some device manufacturers who have specified FISCO approvals for their devices but not Entity approvals, and with some older devices that have Entity approvals but not FISCO.

A recent enhancement in split-architecture systems incorporates FISCO compatibility at the field device coupler. Having FISCO and Entity compatibility at the device coupler in a split-architecture design enables all users to implement intrinsically safe fieldbus with any desired mix of approved devices without the limitations in cable lengths and reduction in MTBF that results from a pure FISCO system. Fig. 3 shows a commercially available split-architecture system as used on a pharmaceutical plant, and Table 1 shows a comparison between the three types of intrinsically safe fieldbus segment design.

The revised split-architecture approach therefore solves all the issues related to making intrinsically safe fieldbus practical, affordable and safe. The segment can be designed with loads of up to 350 mA, cables of 1,900-m trunk and 120-m spurs. The segment can incorporate redundant power supplies for the very highest MTBF and the field devices can be mixtures of Entity or FISCO approvals as required. Safety considerations are greatly simplified to a couple of calculations per system, and users can be confident that their intrinsically safe fieldbus implementation has the same degree of safety and security as any conventional segment design. **HP**

Mike O'Neill is director, MooreHawke Fieldbus Division of Moore Industries-International, Inc, working from the UK offices of Moore Industries Europe. He graduated from Cardiff University in 1978 and joined Kent Instruments and Taylor Instruments for his initial experience in process control systems. Mr. O'Neill subsequently progressed through various product management and consultancy positions at hazardous area specialist MTL before joining Hawke Cable Glands in 2001 to head up its fieldbus product development. Moore Industries-International, Inc. acquired that product line in 2005 and he was appointed director for fieldbus at the new MooreHawke Fieldbus Division. Mr. O'Neill is a member of the Institute of Measurement & Control (UK) and has written and presented extensively on fieldbus systems implementation, with particular expertise in physical layer and hazardous-area applications. He is an active contributor to all things fieldbus, and is currently team leader at FOUNDATION fieldbus for developing test specifications for fieldbus device couplers.