Fieldbus in the Process Control Laboratory – Its Time Has Come

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Abstract *- Industrial process control has evolved following the path of Direct Digital Control (DDC-1962), Programmable Logic Controllers (PLC-1972), Distributed Control Systems (DCS-1976), and Field Control Systems (FCS-1994). The latest Field Control System evolution that is taking place is the implementation of Foundation fieldbus (FF) into the manufacturing environment. This article describes Foundation fieldbus, its role in a plant network hierarchy, and a comparison between Foundation fieldbus and the older DCS model. In addition, this article discusses instructional issues associated with teaching Foundation fieldbus in a system control course and laboratory, along with an overview of the hardware and software necessary to build a network of Foundation fieldbus devices through integration of FF on existing process trainers.*

Introduction

Foundation fieldbus is a digital control network that interlinks "smart" sensors and actuators in a manufacturing environment. It is the latest technology used to automate the capture of process data and the control of production systems. The evolution of the system architecture from Direct Digital Control (DDC) to Distributed Control Systems (DCS) and now to Field Control Systems (FCS) is illustrated in Figure 1. In every step of the evolution, the control of the process has moved closer to the sensors and actuators.

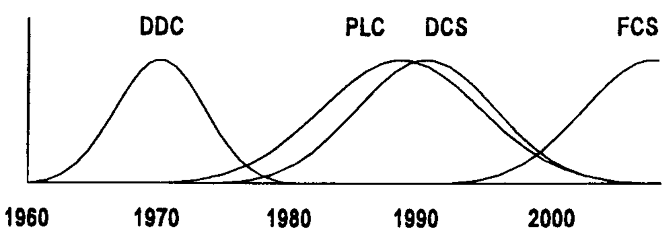

Figure 1 Control Evolution [1]

Figure 2 illustrates the shift of the proportional-integral-differential (PID) function from the primary system computer to the sensors and actuators at the point of measurement and control. This movement of the control process reduces wiring, aids in troubleshooting, and decreases maintenance costs of the industrial control network. It also allows fieldbus devices to be controlled by any Fieldbus host computer on an existing plant Local Area Network (LAN) with the appropriate interface to the fieldbus system.

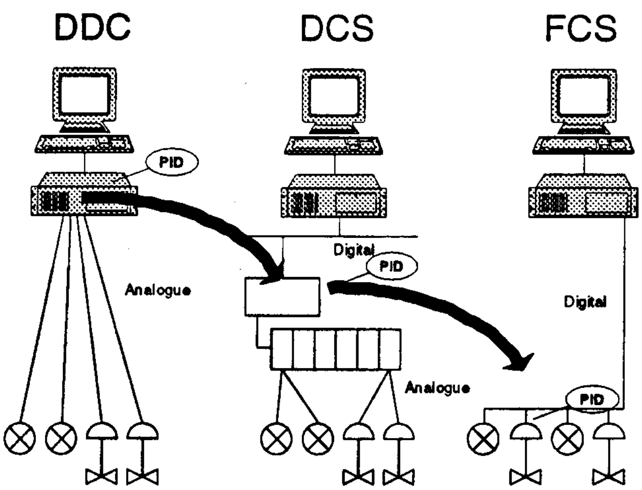

Figure 2 Control Architecture [1]

Another feature of the FF system is the capability of adding fieldbus devices to an existing fieldbus process while it is operational. This makes the implementation of new fieldbus networks into an existing system a less complex process and does not require that the process be shutdown when sensors are replaced or new field devices are added.

Fieldbus devices have the ability to run process control loops internally without having any need for processing power from a central computer or digital processor on the network. In addition to the data networking function, the FF twisted-pair network cable can supply the power required to run all the sensors and actuators on the network. The standard requires that up to 32 devices can be on a single segment. By using repeaters, as many as 240 fieldbus devices can be on a single network.

The FF standard of interoperability supports "Plug and Play" architecture. This allows field devices from different vendors o be mixed in a working fieldbus model and the addition of new field devices without the need for major LAN reconfiguration.

Fieldbus Systems and Standards

The number of network control techniques, using the term *fieldbus* to describe their operation, is numerous. As a result, a considerable level of confusion exists in the selection and design of fieldbus driven control system. The chart in Figure 3 provides an overview of the current network protocol

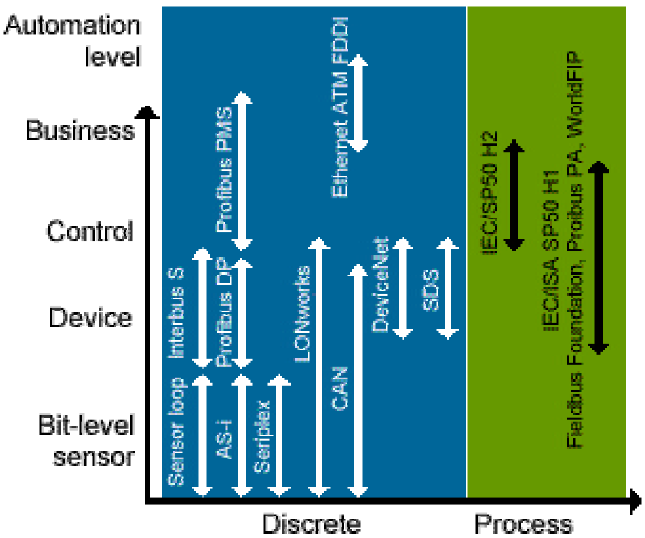

Figure 3 Fieldbus LAN Options [2]

choices available to the design engineer. The fieldbus LANs are divided into the two broad application categories of *discrete* and *process*. The level of automation available further differentiates the choices from bit-level sensor operation to support for the process control and interfaces into the business unit for databases management and inventory control. In the discrete area, the Profibus DP, CAN, Devicenet, and SDS protocols have good vendor support. On the process control side, two protocols predominate: the Fieldbus Foundation and Profibus PA.

Development of the fieldbus standard started in the mid-1980s when the Instrument Society of America (ISA) formed the SP50 fieldbus committee. In 1992, the number of variations in the standard narrowed when Fisher, Rosemount, Yokogawa, and Siemens created the Interoperable Systems Project (ISP) and the other major SP50 companies, including Honeywell, Allen Bradley, and others formed the WorldFIP standard group [2]. Further consolidation occurred in 1993 when the ISP and WorldFIP joined to form the Fieldbus Foundation (FF). As a result, two protocols have evolved for LAN based process control applications: the Fieldbus Foundation, a standard supported in the United States and Asia, while the Profibus PA standard is popular in Europe.

Fieldbus Control Architecture

The architecture used with Foundation fieldbus (FF) configurations includes two LAN types, called H1 and H2. The H1 segment is a 31.25-kbit/sec bus structure used to link FF devices together. The H1 bus, illustrated in Figure 4, can be point to point, bus with spurs or multi-drop, daisy chain, and tree. Type A shielded twisted pair wire is the preferred wire for H1 connections that is specified in the IEC/ISA physical layer standard [3]. A The maximum length 1900

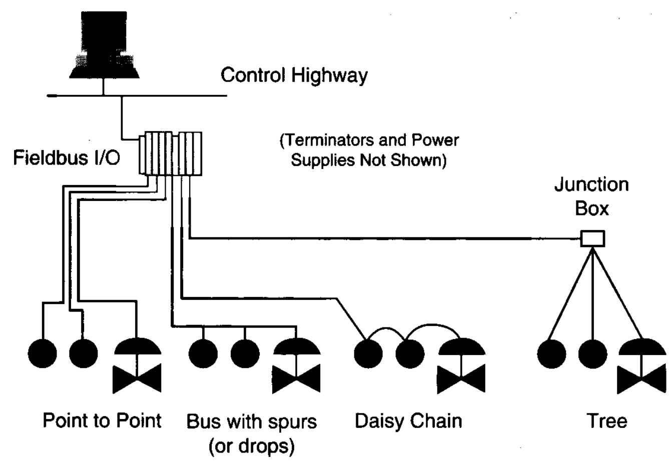

Figure 4 Possible Fieldbus Topologies [3]

meters for H1 cabling is also specified in the same standard. While new installations would use this wire, most current implementations could convert to FF technology using existing instrumentation wiring in most situations.

The expansion block or junction box, illustrated in Figure 5, is used to create the tree or star/chicken-foot topology and to create multiple spurs of the H1 bus at some distance from the FF interface. A typical configuration for expansion blocks is shown in Figure 5. Note that the initial

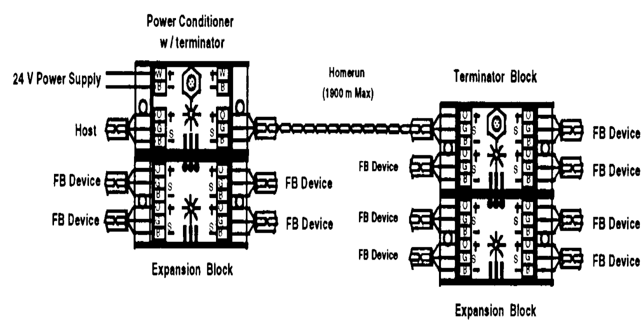

Figure 5 Expansion Blocks [4]

block is a power conditioner plus field device terminator, while subsequent blocks are only used for termination of field devices. The initial block also provides a connection point for the host computer. The H1 bus must also have terminators (a series resistor and capacitor) placed at both ends of the bus to improve network data transmission. Some terminator blocks have terminators built into the interfaces.

A second FF LAN, called H2, is a high-speed fieldbus communications mode, which serves as a backbone for the H1 segments. The H2 backbone can operate at 1, 2.5, or 100 Mbits/s. A typical configuration for an H1 and H2 LAN using FF protocol is shown in Figure 6.

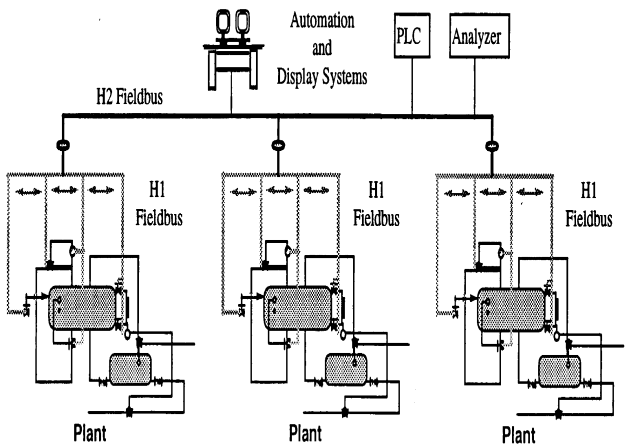

Figure 6 H1 and H2 LAN Structure [4]

The H2 network speeds are useful for transferring data between the smart field devices and other production hardware like programmable logic controllers (PLCs) and process analyzers. The H2 LAN permits access to the fieldbus structure from any computer on a plant intranet, and gives process engineers and production planners direct access to process data and the ability to program the system from remote locations.

Comparison of FF and DCS

The Distributed Control Systems (DCS) is the current standard for large process control applications. In DCS, a central processor, Figure 7, controls all parameters. Fieldbus moves data filtering, conversion, tuning constants, and alarms into the field to be accomplished directly within the fieldbus sensor or actuator (Figure 2). This greatly reduces the need for central processing capability in a fieldbus system. Configuring all device settings, including process parameters, process variables, and set points is possible in the fieldbus system using available configuration tools. Also, the parameter notation has been standardized across FF device manufacturers. This ensures the interoperability between components from different manufacturers and allows the devices to be used in a “Plug and Play” fashion. [6]

In comparison, DCSs have a single process control computer to which all of the sensors and actuators are connected. While the sensors and actuators can come from many different vendors, each device has to be configured to work with the process computer selected. The major advantage of the FF over the DCS is the information and rich data set available to the network from the field device. In the DCS setup, the sensor supplies only values related to the process variable. In contrast, each FF field device has the capability to provide all of the data that would come from the DCS central process computer.

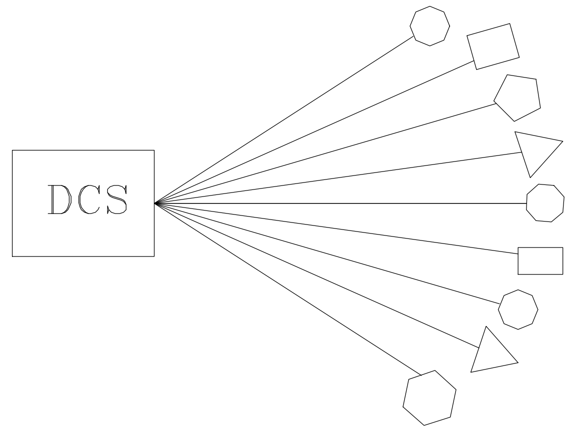

Figure 7 - DCS Process Control Model

Foundation fieldbus systems can coexist with DCS systems. This ensures that existing investments in DCS systems are protected. However, care must be taken in combining the two systems since no existing DCS system can match the functional characteristics of FF. The differences between FF and DCS characteristics can potentially cause confusion and undesirable system operation if devices for one system are used within the network design of the other. [7]

Introduction of Fieldbus into the Laboratory

The first step in creating a Foundation fieldbus system is to select the process to control. Implementations of the fieldbus network in the control laboratory can include a number of process systems, both new and existing. Most process control laboratories in colleges and universities have process trainers for teaching control of temperature, pressure, flow, and level. The 4-20 mA control systems and standalone PID controllers in these simulators can be supplemented by fieldbus devices without losing the 4-20 ma control option.

The hardware and software needed to implement a FF system includes:

- A computer with a FF interface card and FF configuration software.

- A power supply with a dc voltage of 9-32 volts and current capacity of about 20 mA per attached field device.
- The wiring for the 31.25 kHz H1 fieldbus network with a resistance of 100 Ω/ft and an attenuation of 3dB/km maximum. The cabling must be 16-26 gauge twisted shielded pair. The recommended color code is orange or white (+) and blue or black (-). [8,9]
- A terminator composed of a capacitor (1µF) and a resistor (100Ω) to avoid reflection signals in the wire. Terminator blocks with the proper electronics can be purchased or constructed from available components. [8]
- A power conditioner made from an inductor (5mH) and a resistor (50Ω) must be placed between the power supply and the network. [8]

Field devices, such as sensors and actuators, can be purchased from a multitude of companies. Fieldbus Foundation lists all of the companies with Foundation fieldbus standard equipment on their web page [9]. Since the technology is new, relatively few components are currently available compared with the availability of the older 4-20 mA devices. The basic components are temperature sensors, pressure sensors, flow sensors, valve positioners, fieldbus-to-current (4 to 20 mA) converters, and current (4 to 20 mA)-to-fieldbus converters. Additionally, “Round Cards” are available to connect existing 4-20 mA devices into Fieldbus networks.

Modifying an Existing Process Flow Trainer

The fieldbus network and control system, designed for the process control laboratory at Penn State Altoona, utilizes an existing flow process trainer shown in Figure 8. The original unit had a differential pressure transmitter connected across an orifice plate, Figure 9, with the 4 to 20 ma output of the DP unit connected to a variable speed motor controller, Figure 10. The motor controller changes the pumping capacity of a pump to control the fluid flow through the system diagramed in Figure 11. A study of the system layout indicates that it is a straight forward control problem with a tank, single flow loop, pressure orifice, pump, pump motor speed control, and inline visual flow indicator.

In the fieldbus solution the system consists of the same variable speed pump controlled by a Smar fieldbus to current converter (FI-302) and a Honeywell differential pressure sensor (ST3000 ®) illustrated in Figure 12. The network is shown in Figure 13. These components are programmed and configured through a PC with a National Instruments AT-FBUS interface card and the National Instruments "Configurator" software package. This trainer was designed to teach/demonstrate how process flow system components and control software can be configured to maintain a continuous fluid flow, even when a process

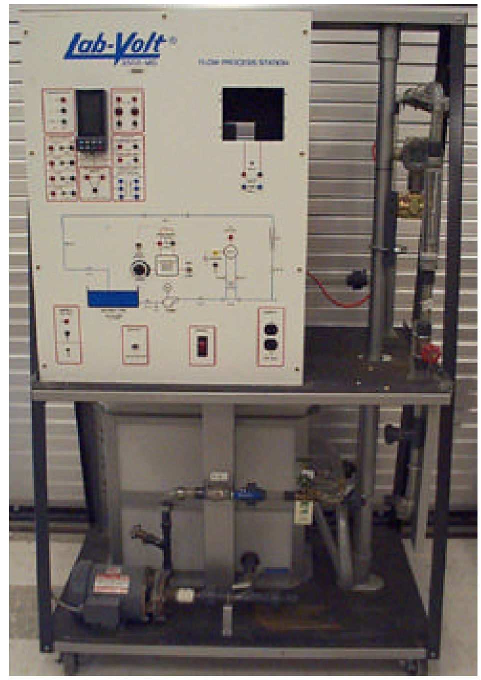

Figure 8 Existing Process Flow Trainer

disturbance is presented to the system. In the original system, the Proportional Integral Differential (PID) control algorithm was implemented in a standalone digital controller. In the fieldbus implementation the differential

Figure 9 Orifice Plate

pressure sensor includes the (PID) controller with internal electronics and software that monitors and controls the fluid flow in the system to a level designated by the user.

The Honeywell DP field device in the fieldbus solution includes a Link Active Scheduler (LAS) program, which is factory installed in their differential pressure sensor. The LAS allows the computer, which is used to configure and monitor the system, to be disconnected from the process network without creating any disruption in the process control or disturbance in the flow control.

Figure 10 Variable Speed Drive

The network configuration for the fieldbus system uses a Smar fieldbus to current converter (FI-302) so that the control parameters from the DP sensors can be interfaced into the existing 4 to 20 ma control of the Seco AC adjustable drive.

All of the laboratory exercises previously performed with the original 4 to 20 ma DP are directly applicable with the fieldbus system. One variation is that students must configure the Honeywell ST3000 differential pressure transmitter, Figure 12, for proper control parameters instead of tuning the digital controller. In addition, students learn to use the Foundation fieldbus configuration program for field devices and to display a much broader range of process data than was available with the standard DP unit.

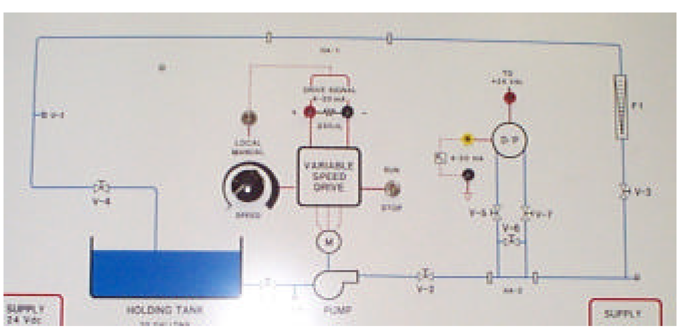

Figure 11 System Flow Schematic

Figure 12 – Honeywell ST-3000 Differential Pressure Transmitter

Future Expansion Plans

Based on the success of the initial FF installation, three additional process trainers will be modified to incorporate Foundation fieldbus technology. These three include a temperature trainer, a liquid level trainer, and a pressure trainer. All four trainers will be linked together utilizing an H2 high-speed (100 MHz) bus. The network to be created is depicted in Figure 14. Additionally, the main computer on the H2 bus can be located at an instructor's station in the lab to monitor the progress of students' work on the FF systems. The central computer can be used by students to test the remote monitoring and control possible with Fieldbus systems. Another advantage of the H2 bus and central computer is the ability of the teacher to inject problems or failures into the local networks, enabling students to troubleshoot real-time failures.

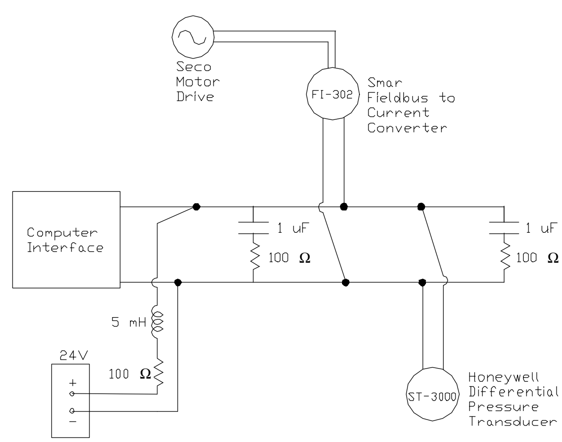

Figure 13 Fieldbus Network for Flow Trainer

The implementation of FF on the three additional trainers is similar to the efforts used to convert the Flow Process trainer. The major difference is in selection of the appropriate FF transmitters and actuators. Presently, all technology is available to retrofit each trainer with an independent Foundation fieldbus control system and to link the systems with H2 high-speed bus.

Conclusions

Fieldbus is the next technology that will find broad use in manufacturing control for the following reasons: it is relatively easy to reduce costs by allowing a user to start with a small system and expand as necessary and financial abilities allow, field wiring is reduced, and troubleshooting of system problems is enhanced. Also, since Foundation fieldbus components are all compatible between companies, anyone can create components for use in Foundation fieldbus systems allowing for greater competition in the market.

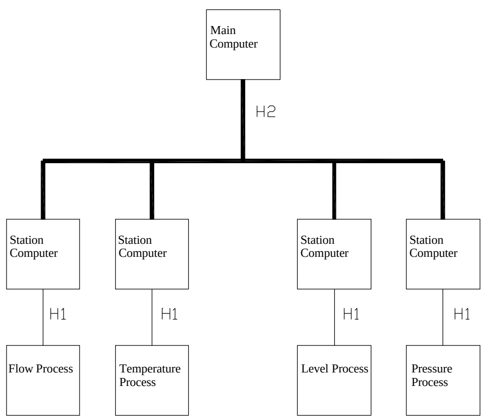

Figure 14 - Future Layout of the Control Lab Network

Because of the anticipated benefits of using a Foundation fieldbus system, it is important to teach Foundation fieldbus in the educational environment. The education of future control engineers in this new technology is the key to moving process control from the distributed control system model to the networked model described by Foundation fieldbus.

Biographies

James Rehg is an assistant professor and Program Coordinator of the B. S. program in Electro-mechanical Engineering Technology at Penn State Altoona. William H. Swain and Brian P. Yangula are senior students in the program and worked on the fieldbus project in their senior project. Steven Wheatman is a Principal Engineer with Honeywell Industrial Automation & Control in Fort Washington, PA.

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