Honeywell

FOUNDATION™ Fieldbus Project Implementation Considerations

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ABSTRACT

FOUNDATION Fieldbus technology has now grown well beyond the initial development and commercialization phase and is fast becoming an accepted element of process control projects. In one man's words, "It has achieved critical mass." But this mainstream status has many users unaware of the potential differences of this technology compared to conventional process control devices. Fieldbus offers many benefits and advantages to the user. However, it requires not only an understanding of the technology but some differences in thinking about how to implement projects. Examples range from bus power distribution, wiring practices, and function blocks to project scheduling and plant personnel capabilities. The purpose of this paper is to explore some of these areas and provide insight that will help in the planning and execution of projects involving FOUNDATION Fieldbus.

INTRODUCTION

By now nearly everyone has heard about the benefits of FOUNDATION Fieldbus technology. Lower your wiring costs! Commission and start up plants in less time! Provide your operators with more meaningful information! Avoid unnecessary and costly downtime incidents! And lower the cost of maintenance! Despite occasionally exaggerated claims, there is plenty of evidence that the benefits of this technology are both real and substantial. Customers who have participated in well-managed projects have reported saving money and time in installations. One case in point is a recent Honeywell project involving nearly 700 Fieldbus devices that reported a savings of more than $70,000 in equipment costs alone. A smaller footprint through elimination of I/O cabinets helped reduce the facility's overall wiring needs. Other intangible benefits, such as ease of configuration and maintenance, have been reported as well.

Getting to this point requires understanding the details of Fieldbus and applying this understanding to specific facets of process control system project planning. Failure to do so can easily result in lost time, endless hours of troubleshooting and a loss of these very significant savings. Some specific aspects of FOUNDATION Fieldbus technology that bear close attention include wiring topology, power distribution, and general wiring practices such as grounding and shielding. Other aspects that are unique to Fieldbus include function block residency, network bandwidth and scheduling, device address limitations, and overall "system" capacity. All of these areas have impact on project implementation, most notably on project scheduling itself. Tasks such as configuration and testing must be thought of differently from conventional control system projects.

UNIQUE FIELDBUS TECHNOLOGIES

Before we can talk about planning and implementation differences between Fieldbus and conventional projects, we need to understand some of the technical aspects of FOUNDATION Fieldbus that make it unique. We can't cover everything, but lets take a look at some "heavy hitters."

FIELDBUS IS A COMMUNICATION NETWORK!

If you have not yet done so, read the FOUNDATION Fieldbus Technical Overview[1] published by the Fieldbus Foundation. It is available from the Internet at http://www.fieldbus.org/. Gaining at least this much understanding is extremely important (the document just covers the essentials), and failure to do so can result in a great deal of wasted effort. As this document describes, the most fundamental principle of Fieldbus is that it is a communication network, specifically one operating at 31.25 kbit/s, for interconnecting process measurement and control equipment such as sensors, actuators and controllers. In addition, this network (referred to as H1) is bus-powered, meaning that devices derive power from the bus as well as communicate on it. A detailed understanding of how the network works is not critical, but there are some very important rules and guidelines[2] which must be understood.

The length and number of devices on a Fieldbus network are limited by power distribution, attenuation and signal distortion. There are a number of rules (based on fundamental principles as well as practical experience) used to calculate H1 loading and length limits, and these are well documented in publications by the Foundation, Relcom Inc[3], and others. Since applying these rules can be a bit tricky, a free spreadsheet tool is available from Honeywell that performs the calculations[4]. Regardless of the tool used, it is important to understand a few nuances of Fieldbus. For example, different power conditioners (component that prevents signals from getting absorbed by the power supply) support different current limits and can make a big difference in the bus length and number of devices supportable. If you are dealing with intrinsically safe (IS) installations, the use of safety barriers forces a lower current rating which generally limits you to 3 or 4 devices on an H1 network. The use of IS repeaters allows extending the number of devices on the network by essentially starting a new electrical segment.

GENERAL FIELDBUS WIRING PRACTICES

Fieldbus uses twisted pair, shielded cabling to minimize external noise on the network. Networks must be properly grounded and terminated. Although Fieldbus cable specs may be similar to those of 4-20 mA devices and allow for use of existing wiring, many Fieldbus projects have run into noise problems when using older wiring with inadequate shielding or improper grounding. Noise is the most frequently reported problem with Fieldbus installations and is completely preventable. For new installations to get maximum performance from Fieldbus, twisted-pair cable designed especially for Fieldbus should always be used. You are going to save on wiring with Fieldbus, so this is not the place to try to save a few bucks by sacrificing quality! The referenced Fieldbus wiring publication contains estimates of how long a Fieldbus cable can be and still get adequate signal quality for four different types of cable – individual shielded twisted pair, multiple shielded twisted pair, multiple unshielded twisted pair, and multiple conductor unshielded. You should pay close attention to this.

Once again, refer to the Foundation's FOUNDATION Fieldbus Wiring and Installation Application Guide[2] publication for important rules and guidelines. It cannot be emphasized enough how important these practices are to a successful Fieldbus implementation project.

FIELDBUS WIRING TOPOLOGY

Traditional 4-20 mA and discrete signals involve point-to-point wiring, with each signal usually requiring a pair of wires. With numerous devices on a single H1 Fieldbus link and multiple signals coming from some devices, it is easy to see why Fieldbus offers some very attractive opportunities for wiring savings. But it is very important to understand what topologies are possible and recognize that some make more sense than others.

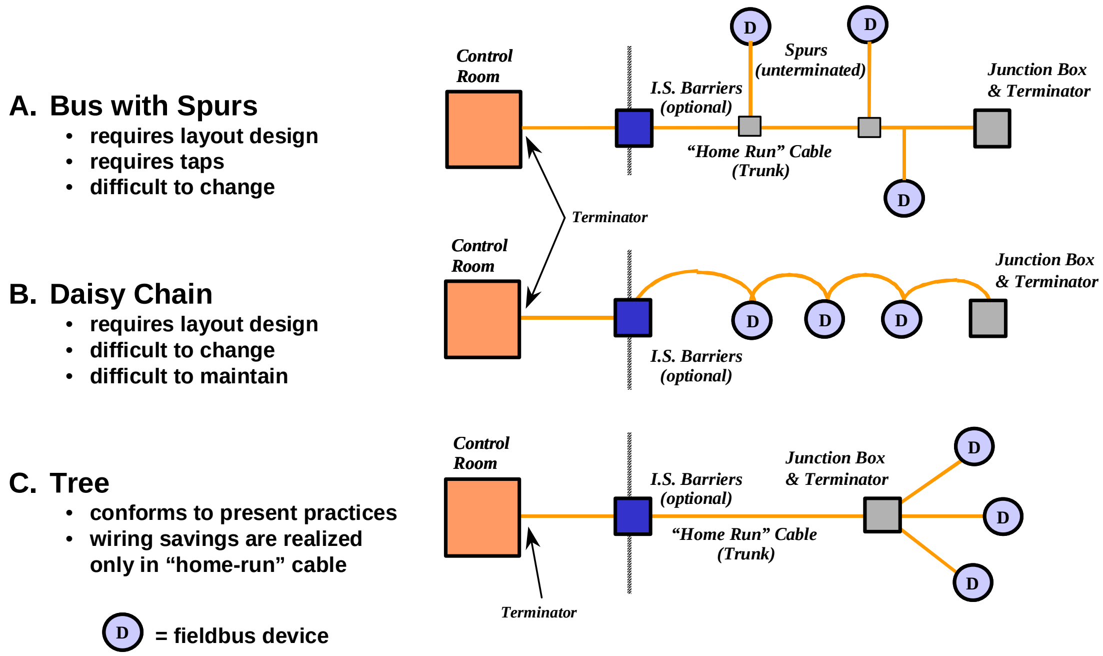

Figure 1. Typical Fieldbus Topologies

Figure 1 is a simplified diagram of three general topologies for Fieldbus networks. Although all three are electrically correct, Topology C, the Tree configuration (sometimes referred to as a "Chicken Foot" configuration), is the most widely accepted and is used for several reasons. The most obvious is that devices can be removed and added without network interruption, for example for device replacement or expansion. In this example, the Daisy Chain configuration requires downstream devices to be disconnected, so maintenance in a live environment is very difficult for Topology B. Topology C also offers the best wiring savings, as most applications involve long runs between the control room and field, with instruments in a cluster. A combined version of Topologies A and C, with two or more junction boxes along a home run, is also popular with the Fieldbus wiring products available today. So, unlike conventional instrumentation wiring practices, a Fieldbus project involves understanding topology requirements and planning accordingly.

FIELDBUS POWER DISTRIBUTION

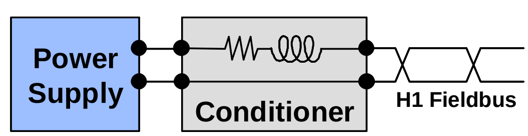

Figure 2. Fieldbus Power Conditioning

Mention was made earlier that Fieldbus H1 networks are bus powered. As described by Relcom[3], it is important to understand that powering the bus involves placing a "conditioner" (the electrical equivalent of a 5 mH inductor in series with a 50 Ω resistor) between the power source (generally 24 VDC) and the H1 bus (see Figure 2). This allows devices to communicate while still being provided power. The inductor provides the impedance isolation, while the resistor prevents the network from "ringing." This design standard results in a current limitation of about 400 mA for general-purpose use, but available conditioners that meet different electrical safety standards have different current ratings. Some devices use passive components and generally deliver lower current and voltage, while others contain active circuitry and provide higher current and voltage. Very close attention should be paid to the current, voltage and safety ratings of different conditioners, especially those for intrinsic safety use. These ratings represent the available power on the H1 Fieldbus network.

Likewise, close attention must be paid to device current ratings. Today's bus-powered devices generally consume from 15 to 30 mA per device, with actuators consuming the most power. We can expect to see devices in the future with even lower current ratings. Since current consumption information can be hard to find, a well-kept secret is that power ratings are usually included in device CFF (Common File Format) files. Just look for the `PowerRequired` parameter (which should be expressed in mA). Some devices, such as mass flowmeters, are self-powered (meaning they require a separate AC or DC power connection), but still may consume some amount of bus power.

Power distribution calculations take into account available conditioned current and current consumption of each device. A very important consideration is the resistance of the H1 Fieldbus wiring. A common mistake is to forget to take this into account. Don't forget to double the distance, as *two* wires are involved! As can be seen, this is clearly an area that is markedly different from conventional instrumentation practices. Once again, use of a proven tool for performing wiring calculations is highly recommended and can make the planning job much easier.

FUNCTION BLOCK RESIDENCY – WHERE IS MY CONTROL SYSTEM?

The FOUNDATION Fieldbus concept of control function blocks (FBs) residing and executing in devices is different from that of conventional instrumentation and distinct from most other bus philosophies. The idea of control in the field is nothing new – pneumatic devices have been running in the field for decades and have included control algorithms like PID. But these devices were not "integrated" into the control system. The control system could be configured and tested without the presence of the field devices and later "bolted" together.

With Fieldbus, it is possible for some level of control to be executing "on the wire" (that is, in devices on the bus) without any help from the host control system. It is also possible for control to be integrated with the control system, with the line between field device and host controller completely transparent to the operator. Reasons for using one approach over the other depend for the most part on application. A simple illustration of the two approaches is given in Figure 3, where PID (proportional-integral-derivative) control is shown executing in the host controller (left example) versus in a Fieldbus device (right example). Although the two approaches are very different at the "system" level, those differences can be nearly invisible to the operator and engineer. From a P&ID drawing perspective, there are really no differences.

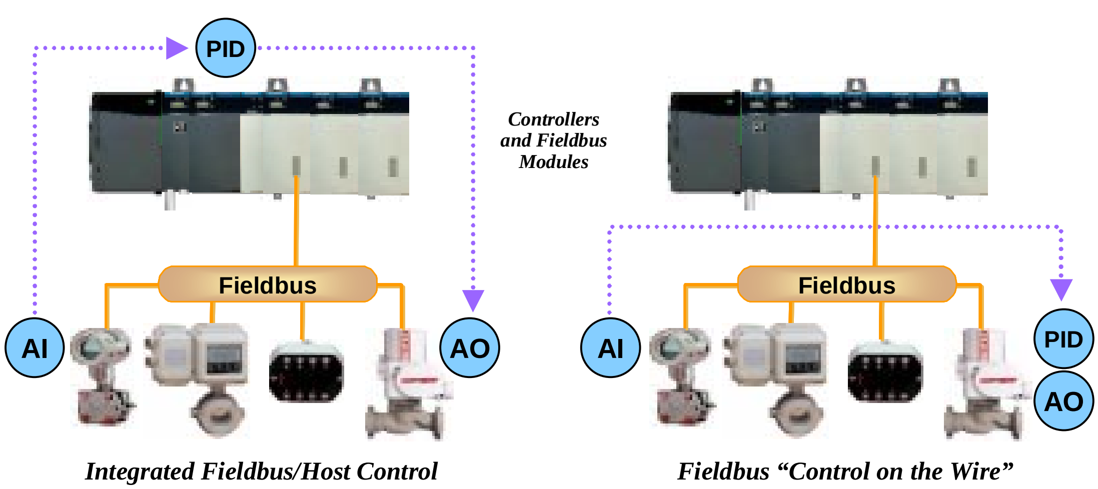

Figure 3. Function Block Residency Example

Regardless of the approach, it must be recognized that the control schemes and databases are located in *both* the host control system *and* the devices. That is the basic answer to the question, "Where is My Control System?" Configuration activities can be done off-line, but eventually the devices must meet the control system before startup in order to test all of the control connections. Besides, configuration of instruments is a very large part of the job. This is very important when considering project planning, because devices generally go to the plant site and not necessarily to the same location as the control system.

NETWORK BANDWIDTH AND SCHEDULING

A common host specification is 16 devices maximum per network. The theoretical limit is higher, but experience and conventional wisdom have shown 8 to 12 devices per link to be a practical maximum and a good rule of thumb. Many customers prefer to set limits, like two output devices maximum per link, to limit risk. Previously discussed electrical factors have to be considered and sometimes may be the governing limitation, but a commonly encountered constraint is link macrocycle scheduling. See Figure 4 below for a graphical display of a typical link macrocycle. Note that the green blocks represent FB execution in devices, the red blocks represent publications on the link, and the yellow blocks represent execution of the host Fieldbus connections ("agents"). Understanding link scheduling is very important. An in-depth discussion of link scheduling is beyond the scope of this paper, but here are a few important things to consider:

- FB execution times are critical. Devices on the market today have widely varying FB execution times, and you must know what you are working with. A neat trick is to look in the CFF file and search for the

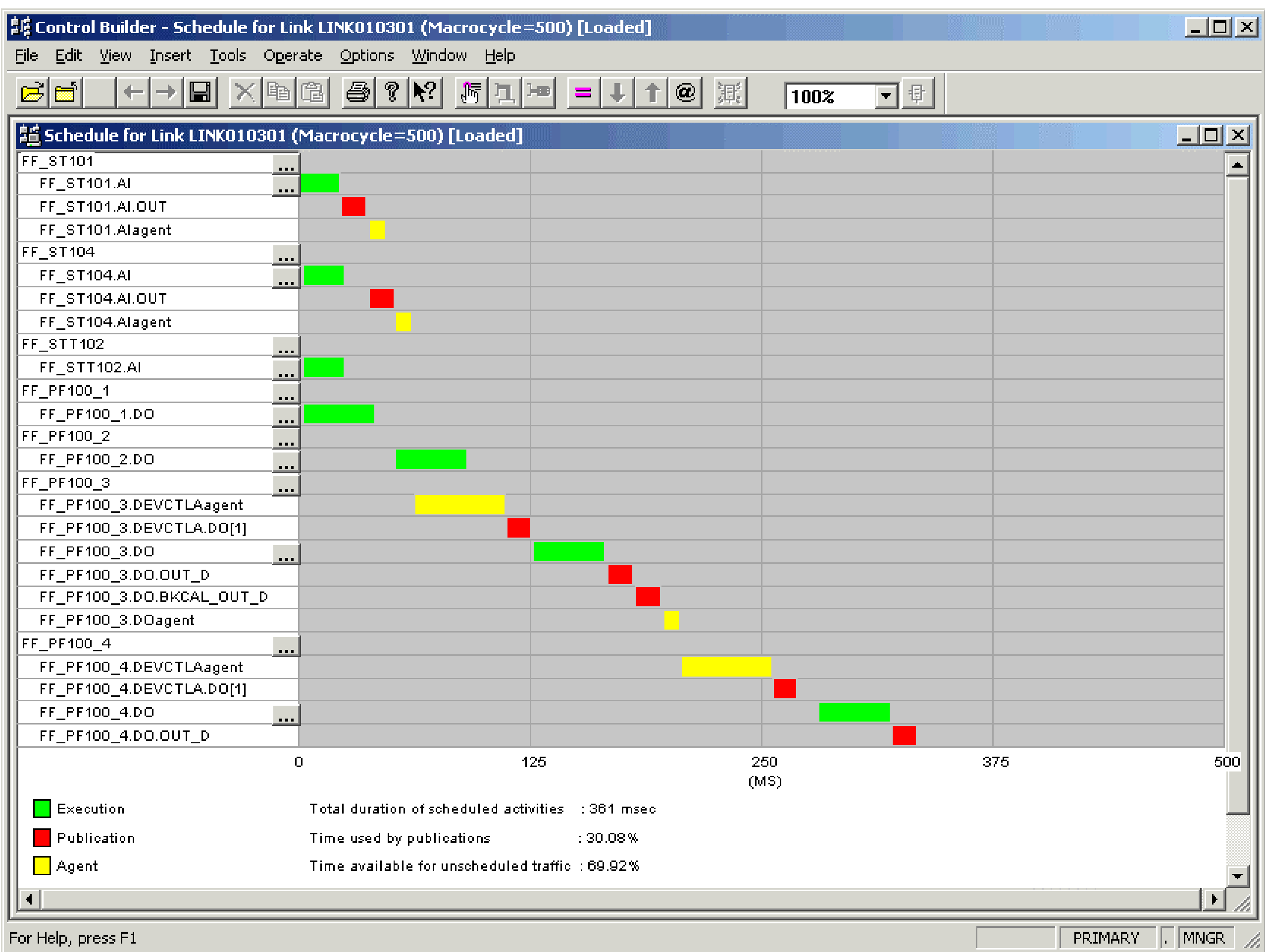

Figure 4. Typical Fieldbus Link Schedule

parameter `EXECUTION_TIME`, expressed in 32,000ths of a second (just divide by 32 to get milliseconds). The Honeywell ST3000 Pressure Transmitter, for example, has an AI FB with `Execution_Time = 736`, corresponding to 23 msec (see FF_ST101.AI in Figure 4).

- Scheduled publications on the link (red blocks) – the ones formed by connecting inputs and outputs – should consume no more than 50% of available bandwidth (in Figure 4, this is labeled as "Time used by publications"). This is to allow for unscheduled events like alarm notifications and general parameter access. If a given link exceeds 50% publication time used, consider increasing the link macrocycle time.
- If it is possible to "pack" publications together, unscheduled link communications will work more smoothly. The idea is a bit like de-fragmenting a disk. Note that Fieldbus publications will *always* work properly regardless of how well "packed" they are.
- Standalone function blocks – those not connected to other blocks – do not consume link bandwidth. For monitoring-only points, consider leaving as standalone blocks. Data access, however, will not be deterministic.
- Function blocks connected within the same device do not consume link bandwidth. A good example is a Fieldbus valve containing both PID and AO FBs. This is a good tip that can help preserve H1 bandwidth.

These are just a few suggestions. Just as understanding the nuances of any control system takes training and experience, the same can be said of Fieldbus technology. This in itself is important to remember.

PROJECT IMPLEMENTATION CONSIDERATIONS

To summarize so far, there are a number of ways in which Fieldbus technology differs considerably from that of conventional process control. Before exploring project implementation considerations, lets briefly review some of the specific key differences:

- Fieldbus is a communication infrastructure, compared with current and voltage signal technology used in conventional instrumentation.
- Fieldbus wiring practices, especially grounding and shielding, are extremely critical. Users should be aware that noise and signal attenuation could have an affect on network performance.
- Power and topology considerations are important to Fieldbus network planning.
- Fieldbus devices are a part of and inseparable from the control system database.
- Fieldbus network capacities are closely related to execution of specific function block control strategies.

Most projects being implemented today still use conventional signal technology for a sizable portion of the project, even if there is new Fieldbus technology present. The planning and execution of a process control project utilizing Fieldbus technology has many similarities to that using conventional technology. As we have seen, however, there are differences for which we must plan accordingly. The following are some of those considerations:

- **Wiring Practices**. Probably the most critical consideration is the wiring itself. As already mentioned, the most frequently reported problem with Fieldbus installations has been noise due to problems with wiring practices. A little planning can go a long way here. The best possible wiring available should always be used. Despite SP50 Committee qualification, unshielded cabling should really not be used. Multiple twisted pair wiring is acceptable, but be aware of lower overall distance limits. Always pay attention to grounding and shielding. When in doubt, measure wiring resistance. This can be very important.
- **Wiring Topology and Connection**. As discussed earlier, always use a tree or modified tree topology; never use a daisy chain topology. Use Fieldbus connection products and practices that allow devices to

be added to and removed from segments without disrupting network communications. This not only allows for expansion and device replacement, but also can greatly facilitate troubleshooting. There are other not so obvious reasons as well! Deciding on the appropriate Fieldbus topology also requires up front decisions about applications planning.

- **Wiring and Power Planning**. Wiring and power calculations are important, and it is important to include some slack in the design (remember scope creep). Use an established tool to do this. In order to do this accurately, you must know what power conditioners will be used (and their electrical characteristics), what devices there will be, what wiring type will be used, and the length of the network. This is a very important part of the project planning!
- **Fieldbus Test Gear**. Many projects wait until they are having trouble with communications before scrambling around for Fieldbus test gear (like Relcom's Fieldbus Testers). Instead of doing this, plan on budgeting up front for test gear and even making the test part of the project. Fieldbus testers can see detailed information about communications that most systems do not pick up (because it would require a performance hit on the part of the communications stack). Testers are particularly good for finding noise and bad connections. Additionally, bus monitors may be helpful in solving difficult communication problems.
- **DD (Device Description) Files**. Pay attention to device revisions and DD/CFF files. A common occurrence is for the customer to receive a set of DD/CFF files long before the devices are received so that off-line configuration can be done. Then, closer to startup, the device received is of a later revision. This is more common for newer devices on the market and less common for more established products, but new product features do happen, meaning new DD/CFF files. When in doubt, always ask your device supplier what revision you will be receiving.
- **Link Capacities**. In the conventional DCS world, systems are often bid to an I/O count, and it is assumed that the controller will handle whatever job needs to be done. Often, specific control requirements are not given or even known. For a Fieldbus H1 link, in the absence of any control application information, a limit of 8-10 devices with a maximum of two actuators is a good rule of thumb. This is how the job mentioned earlier in this paper was handled. But where specific control requirements exist (for example, 2 PID loops at 500 msec plus 6 monitoring transmitters on a link), an examination of network scheduling and bandwidth can be useful. Remember that you can always slow down a loop to achieve capacity, and most systems allow multiple executions speeds on the same link.
- **Topology Design**. In general, if control "on the wire" is a requirement of a given control scheme (say because speed of execution is important), then all devices involved must be on the same H1 link, and this should be planned for. Keep in mind that this is not an issue if the host controller can be involved in the control scheme ("Integrated Fieldbus/Host Control" as shown in Figure 3).
- **Staging and Testing the Control System**. Remember the first rule here: "Devices and their parameters are now part of the control system." Depending on availability or non-availability of FF devices at the Factory Acceptance Test (FAT), some of the activities typically done at FAT cannot be completed to the same extent as in a conventional project. In general that means more time at site and less time at the FAT. One solution that has proven successful has been to make a representative amount of FF devices and equipment available during FAT for test of high-risk configuration structures and software. Unavailability of *any* FF devices at FAT would pose unacceptable project risks and increase work executed at site, while making *all* FF devices present during implementation would reduce project risk but seriously impact project duration and staging/assembly costs. Bear in mind that the FF FBs (AI, PID, AO, etc.) are part of the control database, while device specific information (Transducer block parameters) are really just "owned by the device." The absence of FF devices during FAT impacts:
  - Compile & test of software combined with control on the wire
  - Dynamic test of FF related parameters for HMI
  - Functional test of control using FF devices

Also keep in mind that the degree to which the project is impacted also depends on the relative mix of conventional and Fieldbus Devices.

- **Training and Expertise**. Not enough can be said about the value of expert involvement and training in planning and implementation of projects using Fieldbus technology. Plant project and engineering personnel need to understand the technology during project construction, installation and startup. For example, checking fieldbus links for grounding problems and signal integrity during installation can result in considerable savings over finding these problems later during startup. Instrumentation and maintenance personnel all need to understand how to install, troubleshoot, replace and configure Fieldbus devices. Even operations personnel need to understand ways in which Fieldbus devices differ from conventional devices. One of the important lessons we have learned and seen continuing evidence of is the value of plant ownership. It is the key ingredient in every project's success!

The above list is certainly not all-inclusive, but it covers aspects of nearly all phases of project execution, from planning through startup and finally operation. As can be seen, the addition of Fieldbus to a project affects every phase and provides opportunities to reexamine the way projects are implemented.

SUMMARY

In summary, FOUNDATION Fieldbus technology offers many benefits and advantages to the user, but requires awareness of differences from conventional process control technologies. Successful planning and execution of process control projects requires an understanding of these unique differences and applying this understanding to nearly all phases of the project.

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