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LAYING THE FOUNDATION – BUILDING FIELDBUS SYSTEMS THAT DELIVER BENEFITS

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Abstract: FOUNDATION™ Fieldbus technology has now grown well beyond the initial development and commercialisation phase and is fast becoming an accepted element of process control projects. 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. Issues range from wiring practices, control in field devices and power distribution to project scheduling and plant personnel capabilities. This paper deals with the changes to process planning, documentation, and installation, and with the tools that can simplify and hide the complexities of networking devices in highly distributed control and monitoring environments to deliver real benefits to users.

Keywords: Process Engineering, Configuration Tools, DCS, FOUNDATION Fieldbus, Network

1. Background

In 1985, ISA's Standards and Practices Committee number 50, better known as SP50, was re-convened. This was the same committee that provided the 4-20 mA device interface standard. This time, their charter was to develop a digital communication standard to allow smart, microprocessor-based field devices to communicate using an open standard protocol. FOUNDATION Fieldbus is today's protocol that resulted from the completed physical and data link layers, and spirit of the user layer from the work of the SP50 Committee.

2. Introduction

It is reasonable to expect that almost every person involved in process control and process automation systems has heard about the benefits of FOUNDATION Fieldbus technology. Reduce your wiring costs! Commission and start up plants in less time! Provide your operators with more meaningful information! Avoid unnecessary and costly downtime! 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.

End users who have participated in well-managed projects have reported saving money and time in installations. 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, hours of troubleshooting and a loss of these 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 addressing, 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.

3. What is FOUNDATION Fieldbus?

Before dealing with 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. The salient features of FOUNDATION Fieldbus are (Ref 1):

- A bi-directional, digital, process control communications protocol, which includes physical, data link and application layers.
- A low speed network at 31.25 kbps that provides device power via the bus and optionally supports intrinsically safe device operation. Topologies include bus with spurs, daisy chain, tree, and hybrids of these.
- A high speed network using Ethernet at 100 Mbps that is not intrinsically safe and does not provide bus power. Topology is a star through switched network infrastructure.
- A user-layer that includes a robust set of process control function blocks to provide interoperable, device-resident capable control.
- Device-descriptive files provided by the device manufacturers in order to allow configuration devices and interface devices to automatically and intimately understand how to interface to the devices in a fully interoperable manner.

- The capability for a device manufacturer to extend function blocks by providing additional parameters and features. Also the ability to provide manufacturer-specific function blocks.
- A data link layer that synchronises the function block execution and the publication of data on the bus in order to provide predictable loop performance with minimal latency.

4. What needs to be engineered?

With conventional 4-20 mA signalling, engineering is required for the wiring from the devices to the controllers and the consideration of which functions relate to one another (hence logically belong in the same controller), and what the controller capacity limit is in terms of numbers of functions executed at certain periods.

4.1. Wiring Topology

Fieldbus changes the wiring topology considerably. Point-to-point wiring generally gives way to a single home run cable with short spurs or a multi-drop bus with short spurs. Rules defined by the ISA's SP50.02 standard, limit the length of the H1 segment to 1900 metres for a quality grade of cable (individually shielded twisted pairs) plus a total of 120 metres of spurs. Repeaters can be used to extend the physical segment length. The standard also dictates the maximum length of each spur as a function of the number of devices on the bus. The more devices, the shorter the spurs can be. (For example, a segment with 15 devices can only have spurs of 60 metres length total while a segment with only 2 devices can tolerate 120 metres of spurs.) Spreadsheets are available to help with the calculations associated with segment design. (Ref. 2)

4.2. Power Distribution

It is costly to run extra wires to field devices just to power them. Most Fieldbus devices obtain operating power from the same bus that is used for communications. The current draw of each device must be ascertained and an adequate power supply, usually at the host interface, provided. Typical devices consume current in the range of 12 to 25 mA and supplies are available that provide 350 mA to 700 mA of current or more, per segment. Note that powering the bus involves placing a conditioning element between the power source (normally 24 VDC) and the H1 bus (Fig 1). Fieldbus compliant power supplies have the conditioning elements built in and redundant power supplies are available.

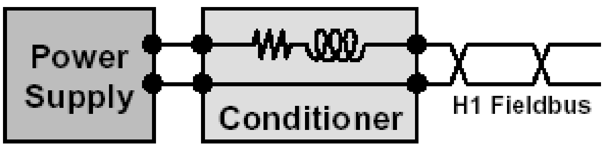

Fig 1 - Fieldbus Power Conditioning

4.3. Function Block Residency – Where is my Control System?

The FOUNDATION Fieldbus concept of control function blocks residing and executing in devices is different from that of conventional instrumentation and distinct from most other “fieldbus” 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.

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.

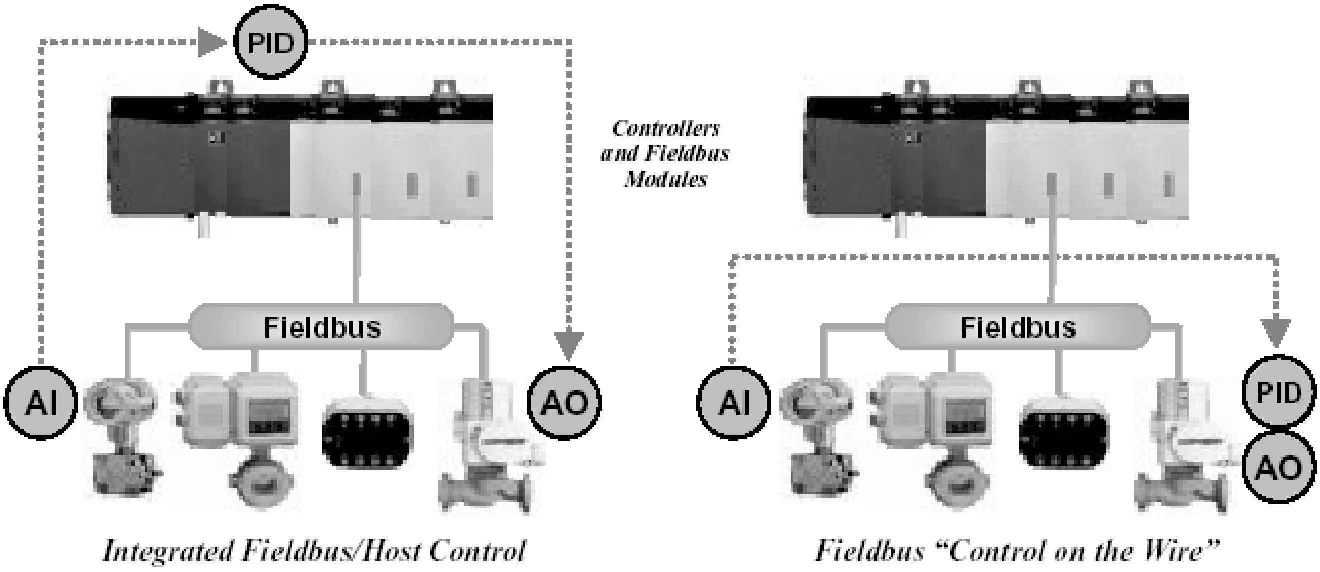

Fig 2 - Function Block Residency Example

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 Fig 2, where PID 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.

Considerations for locating specific processing functions in devices or host controllers include:

- Availability of best-in-class functionality in the desired devices versus host
- Control latency through a controller versus directly on the bus, and
- Co-location of devices on a single segment versus the need to bridge multiple segments due to physical constraints.

Note that from a P&ID perspective, there is really no difference where the control is executed.

Regardless of the approach, it must be recognised 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 start-up in order to test all of the control connections. 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 site for installation and not necessarily to the same location as the control system hardware.

4.4. Network Scheduling

The FOUNDATION Fieldbus network is a scheduled network. The fundamental user-selectable time period is called the macrocycle. Within the macrocycle, function blocks are scheduled for execution at particular phases and after their execution, their relevant data is scheduled for publication. There can be multiple loops in the same macrocycle operating at different periods as long as the longest period is an exact multiple of each of the shorter periods.

A common host specification is 16 devices maximum per segment. The theoretical limit is higher, but experience and conventional wisdom have shown 8 to 12 devices per segment to be a practical maximum and a good rule of thumb. Many end users prefer to set limits, like two output devices maximum per segment, to limit risk.

Previously discussed electrical factors have to be considered and sometimes may be the governing limitation, but a common constraint is link macrocycle scheduling. Fig 3 shows a graphical display of a typical link macrocycle.

4.5. Network Bandwidth

As with all communication protocols, bandwidth must be considered also. Time must be available in the macrocycle for demand messages such as alarms and alerts; operator changes, reads for display updates, and downloads. A publication limit of no more than 50% is generally considered reasonable. Since the H1 network operates at 31.25 kbps, 12-to-15 publications per second is a realistic upper performance limit, depending on the device response times and schedule’s optimisation. Optimisation of the link schedule can significantly improve the effectiveness or even the feasibility of a segment. Remember that the more devices present, the slower the macrocycle must be. Conversely, the faster the control frequency, the fewer devices that can be supported on a single segment. You get to engineer the trade-off.

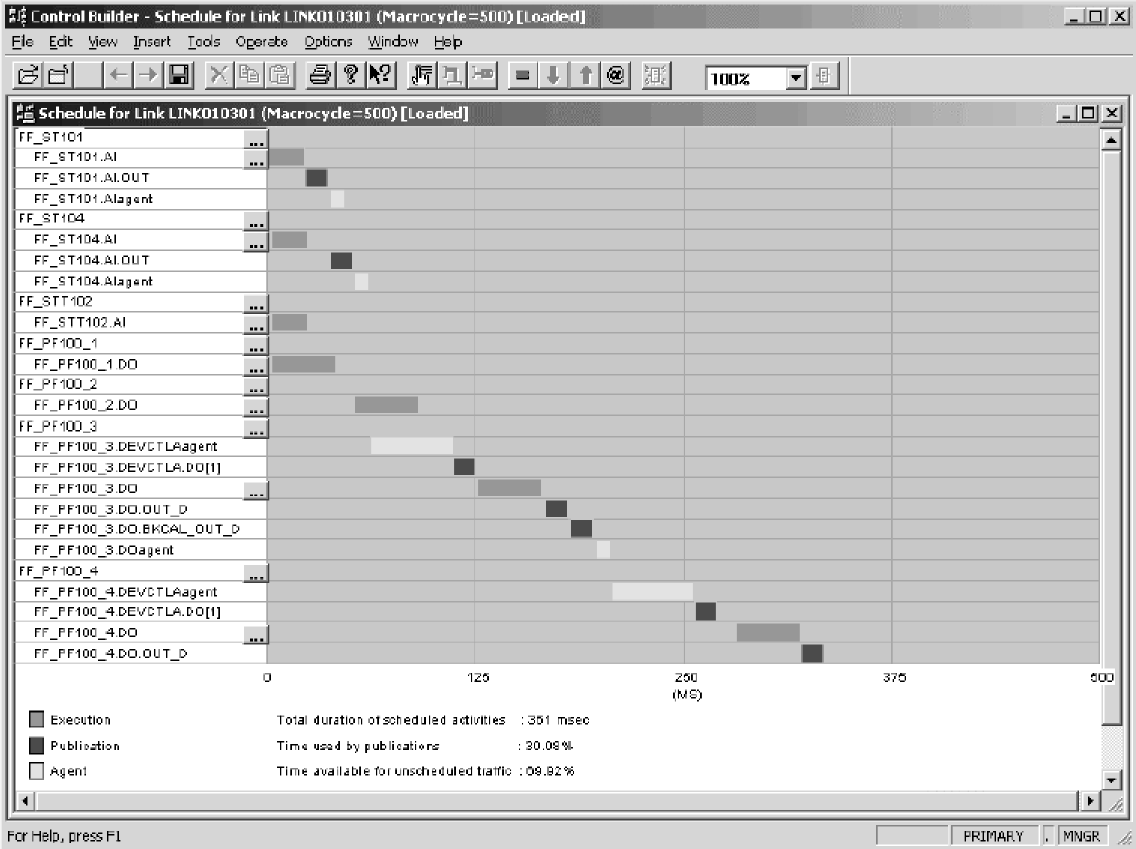

Fig 3 – Typical Fieldbus Link Macrocycle Schedule

4.6. VCRs

A not-well-known limit is the number of Virtual Communications Relationships (VCRs) provided by a device or host interface. A VCR is a logical connection to or from a device or interface that happens to be implemented over a common network. Each Fieldbus device usually needs two VCRs plus one for every subscription or publication that comes into or goes out of it. Each interface device usually needs two VCRs plus one for every subscription or publication that comes into or goes out of it to the devices. The number of VCRs is limited by performance since interrupts must service them in a very short amount of time. Device and host vendors provide the number of available VCRs as a specification detail.

4.7. Dealing with the complexity

Many engineers see the function block configuration in the field devices as a trade-off - it simply moves from the controller to the field device. An integrated engineering environment deals with interconnections between the FF field devices and the controller by configuring both within the same tool, by permitting them to be drawn on the same diagram, and by not having to create special conversion or interface blocks.

5. What documentation needs to be changed?

Here are a few documents to consider: P&IDs, Loop Drawings, SAMA or Control Strategy Diagrams, Data Sheets, and System Drawings:

P&IDs: Piping and Instrumentation Diagrams indicate the process flow and the relative location of instrumentation sensors and actuators. Fieldbus drives little change in these drawings.

Loop Drawings: Loop drawings used to show terminations for wires from the field device through junction boxes, multi-core cables and marshalling cabinets to the terminations for a controller. These terminations are now a part to a powered network. With multidrop networks, the loop drawing should be renamed a “segment drawing” or a “network drawing”. These drawings are still useful for technicians and engineering for control and instrumentation concerns. They will need to show all the devices on a segment, where the power is introduced, where IS barriers are positioned, if used, and where terminators are located. How long is the home run cable? How long is each drop? What types of wires are used? Are there any “rules” violated? Which devices are backup link masters and which are basic? What are the addresses of each device?

SAMA or Control Strategy Diagrams show the function blocks and their interconnections. These are drawn by the configuring engineer using the control system builder configuration tools and may be printed as needed. The primary change here is that some or all of the function blocks reside in the field devices.

Data Sheets are as useful as ever. But now there is more data. Current draw is important, as is network address, maximum VCRs available and number of VCRs used. What permanent function blocks reside in the device? Can others be instantiated? Host system software can help to produce current printouts of device detail information since it can be read from the project copy and can be updated from the device itself, including such details as serial numbers, model numbers, device revision numbers, and materials of construction.

System Drawings are usually a DCS vendor deliverable. They include all the DCS nodes (operator stations, printers, servers, gateways, controllers, I/O chassis, etc.) and the internal networks that interconnect them. These are essential to understanding the infrastructure of the internal and external communications paths.

6. Easing the burden

Given the complexity of Fieldbus technology, why do vendors say Fieldbus is simple? Well, it is complex, but help is available. Look to your experienced host vendor. But make sure they supply comprehensive FF support, not just an “interface”. Do they fully integrate the features, capabilities, and benefits of Fieldbus into the DCS or PAS?

First, ask about on-line versus off-line support. In reality, the pressure of short time-to-market means a plant control strategy has to be worked out well before the equipment is available in the plant. Therefore, off-line, before device-availability configuration is essential. But how does this work? Well, the vendors can provide their device descriptive files long before the devices are installed, shipped, or even manufactured. These files can be obtained from the Fieldbus Foundation, from the device vendors via their web sites, or on a diskette with the devices.

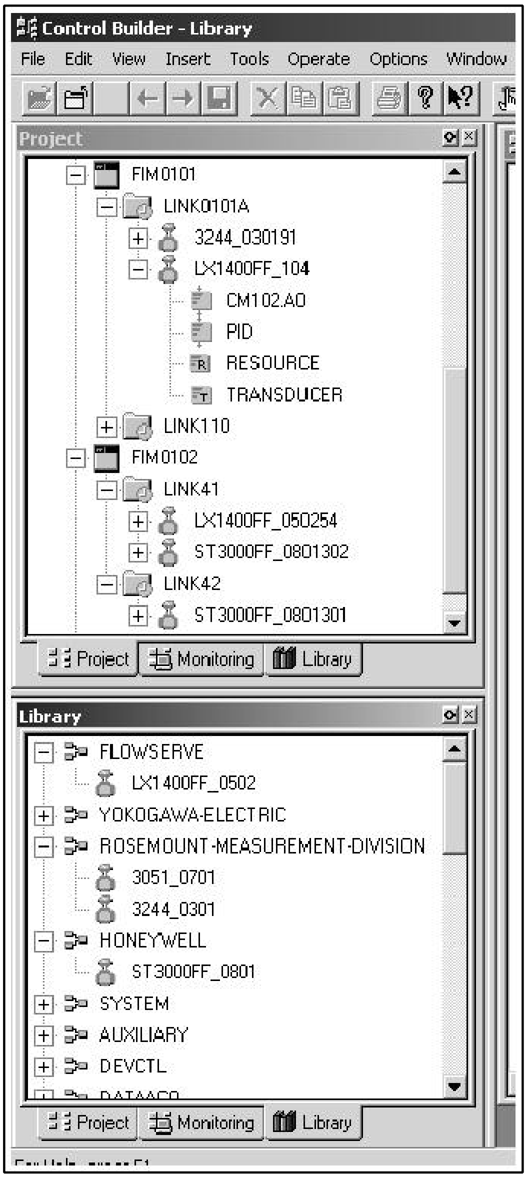

Fig. 4 – Physical Tree Representation

7. Physical and Logical Trees

Windows technology has made us all familiar with the hierarchical "tree" of folders and files that the Windows Explorer presents. That same organisational technique is useful to present first the physical organisation of the Fieldbus, and secondly the control strategy organisation of the Fieldbus. In Fig 4, the physical Fieldbus Interface Modules are presented at the highest level. Subordinate to them, are the multiple FF segments that they support. Subordinate to each segment are the individual devices on the segment. Then, subordinate to the devices are the blocks within each device. Naming of the block indicates the control strategy containing it. By double clicking on the any of these elements, one can get a list of all the parameters, grouped by "tabs" of related functionality.

Similarly, control strategies of sequences of blocks are assigned to controllers, or directly to Fieldbus segments if no controller is needed. Subordinate to these "Control Modules" are the lists of function blocks contained in them. As above, double clicking on any element of the tree, one will get a list of all the related parameters. In both sequences, each element can be collapsed [-] to hide or expanded [+] to reveal the more detailed elements that it contains.

8. Staging and Testing

Depending on 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. This is because the Fieldbus devices are now part of the control system and not just a current loop interface and FATs generally take place about the same time as instrumentation is being installed at the site. In general, this 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.

Non-availability 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. The relative mix of conventional and Fieldbus devices can also complicate FAT.

9. Device commissioning and loading

A control engineer will usually build the strategies in project files long before the device is on the wire. When it is connected to a live network wire, it will show up in the “Uncommissioned Device” section of the tree since the FIM can see it, but it has not yet been associated with the device image in the project file. When the user then matches each uncommissioned device with each device in the project file that has not yet been matched, the alignment of the unique manufacturer-assigned device ID, user-assigned tag, and permanent network address takes place. Loading the device with the project-configured information is the final step in device commissioning.

10. Training

An important but often overlooked element of implementing Fieldbus projects is training. Plant project and engineering personnel need to understand the technology during project construction, installation and startup. For example, checking segments for earthing problems and signal integrity during installation can result in considerable savings over having to locate these problems later during startup. Instrumentation and maintenance personnel need to understand how to install, fault find, replace and configure Fieldbus devices. Even operations personnel need to understand ways in which Fieldbus devices differ from conventional devices.

11. Maintenance

Maintenance is generally considered the compelling reason for Fieldbus. The device’s intelligent diagnostic capability is now an integrated part of the control system. The FF standardised method of reporting notifications enables the DCS vendor to present these alerts to the proper personnel while recording the event without burdening the network with application polling. Bad and uncertain process values are indicated via status indications and automatically propagated so that consuming blocks and applications can take appropriate action.

12. Summary

FOUNDATION Fieldbus technology is complex and 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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13. Abbreviations

DCS - Distributed Control System

FIM – Fieldbus Interface Module

FF – FOUNDATION™ Fieldbus, the technology, or

FF – Fieldbus Foundation, the promotional, not-for-profit organisation

IS – Intrinsic Safety

ISA – Instrumentation, Systems, and Automation Society

kbps - Kilobits per second

Mbps - Megabits per second

PAS – Process Automation System

PID – Proportional, Integral and Derivative

P&ID – Piping & Instrumentation Diagram (Drawing)

SAMA – Scientific Apparatus Makers Association

SP50 - ISA Standards and Practices Committee assigned to Fieldbus standardisation.

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