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USING FOUNDATION™ FIELDBUS IN HYBRID AND BATCH APPLICATIONS

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Abstract: This article looks at how FOUNDATION™ Fieldbus neatly fits into control systems in hybrid and batch applications thanks to recent developments in second generation Fieldbus technology and systems. An overview is given on HSE (High Speed Ethernet), FFB (Flexible Function Block), MIO (Multiple Input/Output), and MVC (Multi-Variable Container) solve real world problems. Products utilizing these technologies and dynamically instantiable function blocks are already available. Several H1 and HSE devices for discrete I/O exist that make hybrid and batch applications possible. Gateway solutions to foreign protocols are also addressed. Finally, a case study illustrates a real example world of how these technologies are applied.

Keywords: Fieldbus, Ethernet, HSE, FFB, MVC, instantiable

1. Introduction

While the superiority of the FOUNDATION™ Fieldbus technology for continuous measurements and regulatory process control is undisputable, some have had doubts about how FOUNDATION™ Fieldbus handles discrete inputs and outputs, and logic as well as sequential control. Indeed to date almost every installation of FOUNDATION™ Fieldbus is a hybrid of its networked and distributed architecture and to some extent that of some conventional analog or discrete devices, and even other network technologies. Where do I apply Fieldbus and where are you forced to stick to conventional technologies? Most importantly, what is the best way to integrate this into one single system? The FOUNDATION™ Fieldbus technology is constantly under development adding new features. New Fieldbus capabilities since its first introduction in the early 1990's includes HSE, FFB, MIO, and MVC. These technologies are already implemented in second-generation Fieldbus systems available from some manufacturers that along with dynamically instantiable function blocks make for very powerful system architecture.

1.1. Hybrid Control

Process plants are predominantly continuous in nature using analog measurements and regulatory controls, but also contain significant amounts of discrete I/O and logic. Although limit switches are often being phased out in favor of transmitters with diagnostics, considerable amounts of discrete still remain. Limit switches, buttons, starters, lights and proximity switches etc. are still all too often connected using discrete parallel wiring. Moreover, although a wide range of device types is available in Fieldbus version there still are some rare measurements and forms of actuation not yet available with Fieldbus communication. Therefore the system must be a hybrid of Fieldbus and conventional I/O.

Other devices, notably Variable Speed Drives (VSD), can connect using conventional I/O but using serial communications such as Modbus allows access to more diagnostics. Therefore there is also a need for gateways to other protocols.

1.2. Batch and Advanced Control

To handle the marshalling of process fluids between processing equipment in a flexible batch plant large amounts of discrete I/O is usually required for solenoid valves and pumps etc. From the perspective of the ISA S88 (IEC 61512) procedural control model the procedures, unit procedures and operations for the procedural logic typically runs in a batch "engine" which usually is a software in a computer whereas the phase logic is executed by the H1 and HSE Fieldbus devices. I.e. Fieldbus is used for the interface to the hardware and for basic control whereas the batch application connects to this phase logic through OPC (OLE for Process Control) that performs the other tasks such as:

- Processing equipment arbitration and dynamic resource allocation
- Recipe testing
- Procedural logic in Sequential Function Chart (SFC)
- Integration with ERP for campaign management

Advanced multivariable control, simulation and inferential measurement are also functions that these days are performed in computers. These software packages are also OPC clients. Thus, in addition to conventional I/O there is also a need for OPC software connectivity.

2. Conventional I/O

Plants usually have a plethora of equipment from different eras. Conventional signals may include inputs and outputs for 3-15 psi pneumatics, 4-20 mA, NAMUR sensors, "dry contacts", NPN/PNP transistors, and triacs etc. Ideally conventional signals shall interface through field-mounted converters because the wiring is reduced and the control loop can be closed within the scope of the H1 network providing single loop integrity and best response. Moreover, future migration from converters to generic Fieldbus instruments will be easier than if a traditional centralized I/O-subsystem in the control room is used.

2.1. I/O Devices

Several types of converters for discrete I/O for FOUNDATION™ H1 Fieldbus already exist. Some have no hazardous area certification and need to be mounted in suitable enclosure but have as many as 16 input and 8 output channels and are able to drive loads as high as 18 W. Other types have 8 inputs and 4 outputs with hazardous area certification and are field mountable. Intrinsically safe (Ex-ia) units can drive small loads typically 9 mW requiring e.g. solenoid valves to be low power. Increased safety (Ex-e) units can drive loads typically 0.7 W.

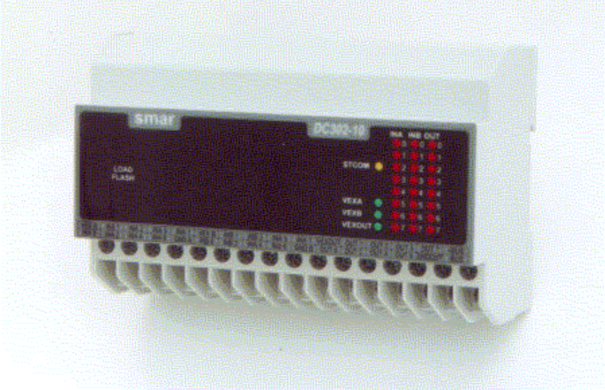

Figure 1 Remote-I/O for FOUNDATION™ Fieldbus H1

Analog converters come in handy when there is a need to convert signals from existing analog devices to Fieldbus. An application for this may be that device must remain analog because the signal is shared between the Fieldbus system and a DCS or PLC. Field mounted analog converters are certified for hazardous areas and may handle 3 channels each.

Figure 2 4-20 mA input and output converters for FOUNDATION™ H1

Linking devices for FOUNDATION™ HSE Fieldbus may also be fitted with conventional I/O-subsystem in a way similar to traditional centralized architectures. Such modular I/O accepts virtually all the common forms of signal inputs and outputs. This may be a solution when field-mounted H1 converters are not available for the type of signal in the application.

Figure 3 FOUNDATION™ HSE linking device with conventional I/O module capability

In a new installation field-mounted converters are clearly better, but in a scenario where an existing DCS or single loop controllers are replaced, while the old conventional instrumentation is maintained, using traditional centralized I/O can still make sense since the wiring is already in place.

2.2. I/O Blocks

Regardless if centralized I/O-subsystem or field-mounted devices are used for conventional I/O, the signals should be made available in the Fieldbus system as FOUNDATION™ Fieldbus function blocks so that the conventional I/O can integrate into the control strategy just like regular H1 and HSE devices. Until recently only single channel AI, AO, DI, and DO blocks were available. These are the most commonly used I/O blocks very well suited for single channel devices such as pressure transmitters and valve positioners. Recently the MIO group of blocks was introduced as part of the Flexible class of function blocks. Multiple-I/O blocks include MAI, MAO, MDI and MDO and they all have eight channels each. MIO blocks may be suitable for traditional centralized I/O with a very large amount of signals.

Another important development is MVC. The MVC capability allows many variables from different blocks, in the same device, to be accessed in a single communication. This reduces the number of transactions required to transport information. E.g. in a multiple channel device using single channel AI, AO, DI, and DO blocks in order to have a neatly structure control strategy, MVC technology can be used in order to communicate their information in a single transaction. The MVC is usually auto-configured by the host computer based on information demand.

MIO are advantageous to device manufacturers because they require less memory than eight individual blocks. MIO blocks can also be used in devices and systems that have no MVC support in order to handle all eight variables in a single communication using the regular View objects.

Another crucial capability is to perform control in the discrete I/O devices in the field. For reasons of performance, availability and safety always strive to close the control loop as close to the process as possible. E.g. if both discrete and analogue devices sit on the H1 field-level, and all logic is done in the field devices, there is no need to go through the centralized controller. Thus single loop integrity is achieved.

3. Foreign Network Integration

Some network enabled devices are not yet available in a Fieldbus version, and a plant may also have some existing equipment based on pre-Fieldbus technologies. Integration with foreign networks is a key capability in order to achieve digital integration in an otherwise heterogeneous environment. Solutions are available.

3.1. Gateway Devices

The drive manufacturers do traditionally not see a motor as a process control instrument and therefore adoption of FOUNDATION™ Fieldbus in a variable speed drive still has not happened. However, pumps and fans are increasingly taking the place of control valves and dampers/louvers, and motors also power conveyor belts, agitators and other equipment in process plants. But many drives can be operated, parameterized and diagnosed using the good old Modbus protocol. HSE Fieldbus linking devices with gateway capability already built-in is already available making it possible for a Fieldbus system to have connectivity with a VSD.

Figure 4 HSE linking device with Modbus gateway capability

Devices of different levels of sophistication communicating using Modbus/RTU or Modbus/TCP can be found in almost every plant. This includes everything from simple local panel, flow computer, weighing scale, RTUs, tank gauging system to whole compressor controls and Emergency Shut Down systems. Thus these devices and subsystem can be integrated through HSE. The gateway is able to work as either a Modbus master or slave making many applications possible. In addition, this device pass through Modbus/RTU frames encapsulated as Modbus/TCP over Ethernet, giving Modbus/TCP applications at the host-level direct access to the Modbus device. The Modbus/TCP frames travel on the same Ethernet media as the HSE frames.

An analog converter for Fieldbus does not handle the smarts of a HART device, but a HART gateway does. A HART gateway for H1 Fieldbus handles both the analog 4-20 mA signals and the digital HART protocol signal at the same time. Versions are available for both analog input and output. One such gateway device already in the market has eight HART communication ports / 4-20 mA channels. The device connects to the H1 Fieldbus network where the HART transmitters will appear much like simple H1 devices.

Figure 5 HART/Fieldbus H1 gateway

In a purely digital mode the HART gateway can operate in multidrop accepting as many as 32 smart instruments.

3.2. Gateway Blocks

To be used in a FOUNDATION™ Fieldbus function block programming language control strategy or be accessed by a Fieldbus host computer the data from a device on a foreign network has to be mapped into Fieldbus function blocks. This can be done in many different ways including flexible function block, MIO blocks or configurable generic custom blocks. A custom block is manufacturer specific while a flexible function block is a framework for creating application specific blocks. Both of these can handle both I/O parameters as well as contained parameters from the foreign network. However, the standard MIO blocks are designed only for analog and digital I/O.

The FOUNDATION™ Fieldbus technology essentially consists of two aspects: a two-tier communication networking architecture and a function block programming language for building control strategies. The FFB comes in handy when there is a need to deviate from these two aspects:

- Incorporate devices on foreign networks
- Incorporate devices with foreign programming languages

Every new FFB created by a user is application specific, i.e. the internal algorithm the block executes and possibly the I/O and contained parameter count and data type depends on the configuration the user makes. In a gateway application the FFB may not have much of an algorithm, it may simply be a collection of parameters mirroring a device on the foreign network. Depending on the level of sophistication of the FFB the block can have exactly the required number of parameters of the desired type. Parameters can also be given meaningful names making the following engineering steps easier. The configuration tool for the foreign network needs to generate block DD for every FFB with user defined parameters created. This DD is application specific DD and loaded into the Fieldbus host computer allowing applications to interpret the data from the user defined FFB.

A custom block is fixed, each having a predetermined number of parameters of each type. More than one custom block, specifically designed for one protocol, may be required for the gateway function in a device. One block may configure the network parameters for the foreign network port, the other block may contain the mapping of individual parameters and the parameter values themselves. E.g. one block configures the Modbus baud rate and node address etc. and the other block the Modbus register numbers and data type for each variable. The advantage of custom blocks is that even simple configuration tools without FFB capability can fully configure the gateway solution and there is no need to manage application specific block DD.

Eventually native Fieldbus variable speed drives will come into the market only requiring a standard AO function block for the control strategy and a drive transducer block for the device configuration such as current and frequency limit, motor ratings, and V/Hz etc.

3.3. OPC

Because there are so many different network protocols and proprietary systems installed and still being sold, there simply isn't gateways to Fieldbus for all of them, not by a long shot. OPC is a technology primarily concerned with bringing data into the software environment such as to a process visualization application. However, OPC technology can also be used as a "software gateway" provided that it is acceptable for the application to pass data from one network to the other through the Windows environment. To achieve this, two OPC-DA servers are linked using an OPC bridge application.

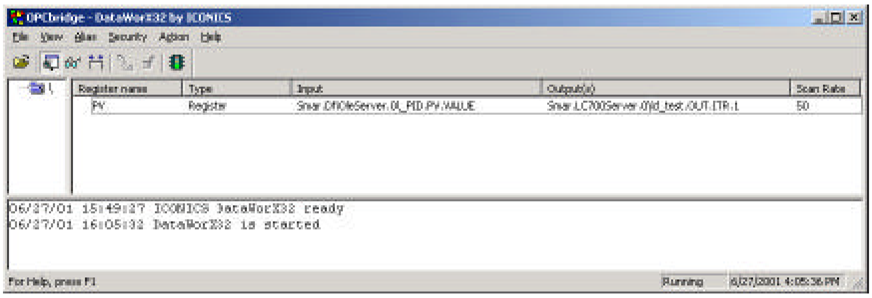

Figure 6 OPC bridge

OPC integrates with FOUNDATION™ Fieldbus at the host-level. Data from linking devices on the HSE network is passed to an OPC server also on the HSE network. Indeed the OPC server at the same time is an HSE host device. The OPC server makes the data available to all kinds of applications such as process visualization, asset management, batch control and advanced multivariable control. OPC is ideal primarily in less time-critical applications in particular for integration of subsystems with lots of data such as a legacy DCS, PLC or ESD. Very time-critical control loops should be closed on the HSE network or even better already on the H1 network close to the field. In the future OPC-DX will take on the soft gateway task displacing the OPC-DA bridging solutions, albeit the solution still relies on computers for OPC servers. Fieldbus Foundation has agreed to support the OPC working group that will produce the DX specification. Because OPC does not have the interoperability, configuration and management capability, safety, redundancy and platform independence of HSE, OPC is only a complement to HSE, not a replacement.

4. Logic and Sequence Control

Function Block Diagram (FBD) is a graphical programming language for building control strategies that is built into the Fieldbus specification and used in H1 as well as HSE devices. The function block execution is tightly scheduled with the publisher/subscriber communication providing the most powerful architecture for distributed control. Standard blocks have a fixed number of inputs, outputs and internal parameters and a pretty rigid internal algorithm only customized through parameterization. However, batch and hybrid applications need logic and sequence control. The FFB makes it possible to integrate programming languages for logic and sequence, e.g. the graphical Ladder Diagram (LD) language is popular since it is easy to visualize executing logic. Ladder diagram is one of the languages in the IEC 61131-3 standard for programmable controller that also includes the Structured Text (ST) language and others.

One of the standard advanced function blocks, the timer, already has some simple logic capability such as AND, OR and NOT etc. in addition to its many timer functions. I.e. for many rudimentary interlock functions the standard timer block together with DI and DO blocks is all you need. If you are using a device that supports dynamically instantiable function blocks more than one timer can be used to achieve the desired functionality. The standard analog alarm block can be used for simple on/off control.

Where more sophisticated logic is required a flexible function block can be used to introduce another language. H1 and HSE devices supporting blocks with user configurable algorithm already exist. The language can execute in the block itself, i.e. essentially a block with a user configurable algorithm, or the language can be executed by other means with the FFB merely acting as a representative within the function block environment.

Depending on the device capability the number of parameters in the flexible function block, their type and their name may either be fixed or programmable. A flexible function block may have its own algorithm or simply act as an interface to another algorithm. Thus there are all-in-all four kinds of flexible function blocks.

4.1. User Block Algorithm

A flexible function block may have the algorithm chosen and modified by the user. This makes it possible for the user to create a block that does exactly what the application requires, e.g. discrete logic with timers, counters, latches and Boolean logic.

Another possibility is a block into which logic statements can be typed directly in structured text-like scripts. The logic is checked and processed by the block itself. A great flexibility in logic configuration is achieved and interoperability also with simple configuration tools is maintained.

4.2. Block for Interfacing

To interface IEC 61131-3 programming languages, and perhaps even proprietary programming languages too, some devices support creation of flexible function blocks with the corresponding inputs, outputs and contained parameters. Although not as elegant as the standard Fieldbus language it makes integration possible. The flexible function block is ideal for integrating the IEC 61131-3 programmable controller languages for discrete control into the Fieldbus environment to complement the regulatory control blocks. When a FFB operates as an interface to another programming language the strategy is configured in an editor and this tools generates application specific DD and CFF files that can be used by a Fieldbus engineering tool to understand the inputs, outputs and exposed contained parameters of the FFB. This means that every programmed FFB is application specific and has its own block specific DD and CFF files that must be managed similar to device support files. Using a foreign language involves more steps and administration and therefore standard blocks should as far as possible be used instead.

Another method to interface foreign control strategy languages is to use standard MIO blocks. Such a solution is already available. The MIO blocks to the PLC act just like eight channel I/O modules accepting inputs from Fieldbus and passing PLC outputs to the Fieldbus environment.

5. Remote Operations

Applications that are widely dispersed geographically must often rely on radio link. Examples of these applications include unmanned platforms, oil fields, pipelines, compressor stations and water reservoirs etc. Long-range industrial grade wireless Ethernet solutions suitable for FOUNDATION™ Fieldbus HSE are now available. Other Ethernet equipment such as IP cameras for surveillance can also be included. Bandwidth is less than for wired Ethernet but far exceeds that of traditional serial radio. Apart from simple process monitoring, HSE provides transparent access to field device diagnostics and configuration etc. Therefore, the advanced diagnostics and other data associated with Fieldbus can be communicated. Remote diagnostics is a particularly valuable feature for unmanned sites that can take hours to reach. Asset management and remote maintenance from a central location becomes possible. HSE linking devices take the place of RTUs. This open solution is poised to eradicate proprietary protocols specific to only one vendor and now allows hardware to be freely selected.

Figure 7 Industrial grade wireless Ethernet

Wireless Ethernet is a frequency hopping radio that requires no license. For long range industrial applications the transmission scheme is slightly different from IEEE 802.11b WiFi and operating in the 900 MHz band making it hard to detect thus preventing spying or overriding of data. Moreover, several internal settings for the frequency hopping makes it very difficult to eavesdrop or even detect the radio. It cannot be stressed enough how much simpler using wireless Ethernet is as compared to traditional RS232 serial radio. With Ethernet, there is no need to configure baud rate, parity, stop bits, flow control and timeouts etc., plus all the DTE/DCE and wiring doubts. Addressing is greatly simplified too, particularly if DHCP is used. In a chain that is typically at least four devices long, eliminating these configuration requirements for every port greatly reduce the number of things that can go wrong. There is not much left you can do wrong, SCADA integration cannot get easier.

Another alternative for remote access is the public Internet made safe with Virtual Private Network (VPN) tunneling and encryption. HSE travels well over the public Internet because HSE is built on IP (the Internet Protocol) that is now being adopted universally. It is possible to enjoy full and complete access to HSE as well as H1 devices with ability to peek all the way down to the sensors without having to configure any web pages or use any web servers. Capabilities go far and beyond mere operator functions such as monitoring, operation and tuning. Asset management function such as instrument configuration, device and sensor diagnostics etc. can also be performed remotely as is network management, configuration download, and firmware upgrades etc. As illustrated at the Fieldbus Foundation press day in December 2001 the robustness of the HSE protocol can also cope with long delays over the public Internet. The trial shows that HSE is suitable not only for a local process control network, but also in remote SCADA/telemetry applications using the Internet or other media with lower quality of service.

6. Application

These solutions for hybrid and batch applications have already been in use for some time and feedback has already been received from the user community. Here are some good pointers. Some devices support both single channel I/O blocks and MIO blocks. It is a good idea to stick to single channel blocks as far as possible, using MIO only when there is not enough memory for a basic block for each channel. An advantage of basic I/O blocks over MIO is that the basic I/O blocks have individual tags corresponding to the attached sensor or actuator making identification easy whereas the eight channels in an MIO block have to share one generic tag. Using individual blocks the channel parameter can be used for soft rewiring of wrongly hardwired sensors. Individual blocks have descriptor, simulation, channel-level diagnostics, analog scaling and discrete inversion, filtering and characterization, as well as other parameters. Single channel blocks makes it possible structure control loops into individual control modules making the configuration easier to read and eliminates the risk that changes to one loop affect others. Moreover, control strategy templates provided with the control systems are typically based on single channel blocks rather than MIO. However, MDI and MDO are quite suitable for discrete applications because much signal conditioning is not done. A single MIO block executes faster than several single channel I/O blocks and is therefore an attractive choice for time critical applications. MAI and MAO may be tricky if conversions are required.

7. Case Study

Carter Holt Harvey's Kraft pulp mill on the north island of New Zealand has been re-instrumented with a second generation Fieldbus system incorporating many of the new technologies discussed in this paper. FOUNDATION™ Fieldbus controls are used for the causticising, white liquor, mud filter, and green liquor processes. The solution chosen was a Smar SYSTEM302 to which the remaining parts of the existing Bailey infi90 and Allen-Bradley PLC5 were integrated.

Figure 8 CHH Tasman pulp mill, limekiln

Regulatory controls as well as totalization and trips are decentralized into the field instruments such as Fieldbus transmitters and positioners. Approximately 40 Fieldbus devices are distributed over four networks connected to a redundant HSE linking device that in turn connects to a redundant Ethernet with redundant OPC servers and workstations.

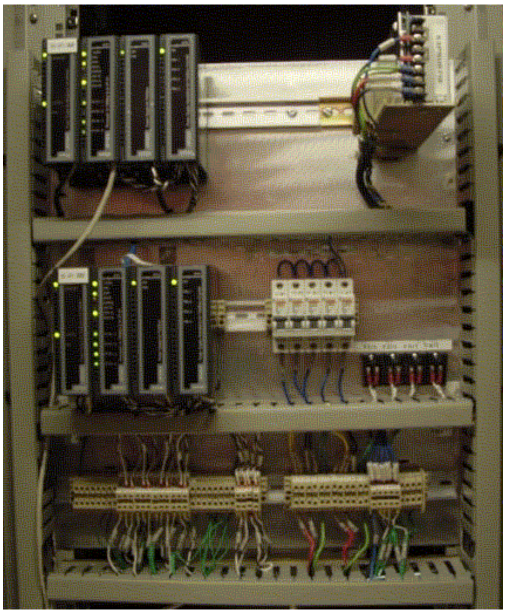

Figure 9 Redundant HSE Linking Devices

A few field-mounted converters are used to bring analog signals from existing conventional instrumentation into the Fieldbus environment. Discrete I/O and logic interlocks are handled by small H1 remote I/O units. One discrete I/O unit is used per network ensuring that the loops are closed within the H1 network, close to the process, thus maintaining single loop integrity.

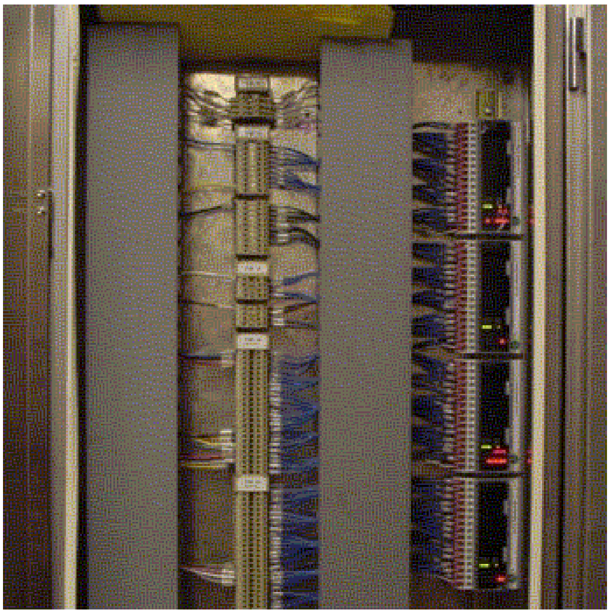

Figure 10 H1 Discrete I/O

The interoperability of FOUNDATION™ Fieldbus comes in handy as H1 devices include Smar but also, Rosemount, Metso and Rosemount Analytical.

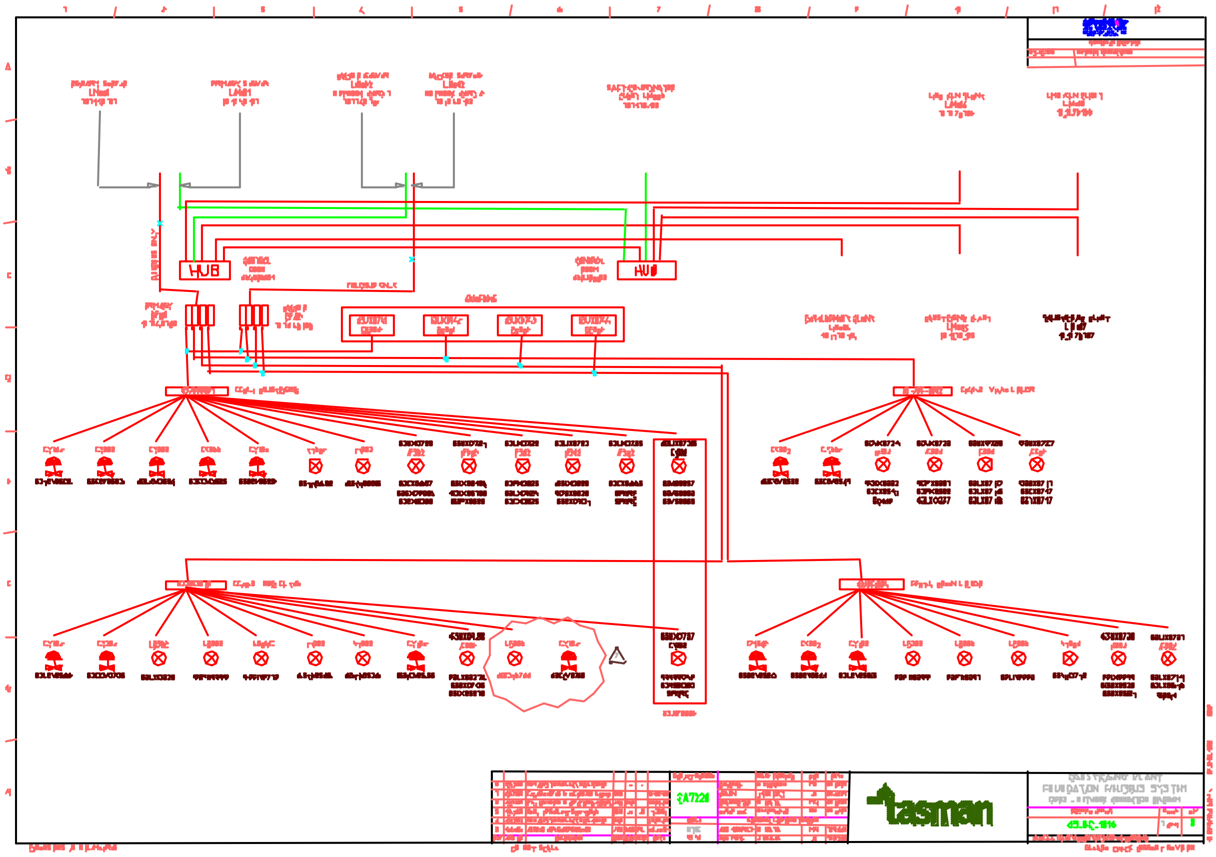

Figure 11 Fieldbus network architecture

All Fieldbus network, device and control strategy configuration is carried out from the integrated engineering tool also used for diagnostics, calibration and other maintenance tasks. A majority of the Fieldbus devices has dynamically instantiable function blocks making it possible to make the control strategy more sophisticated in the future.

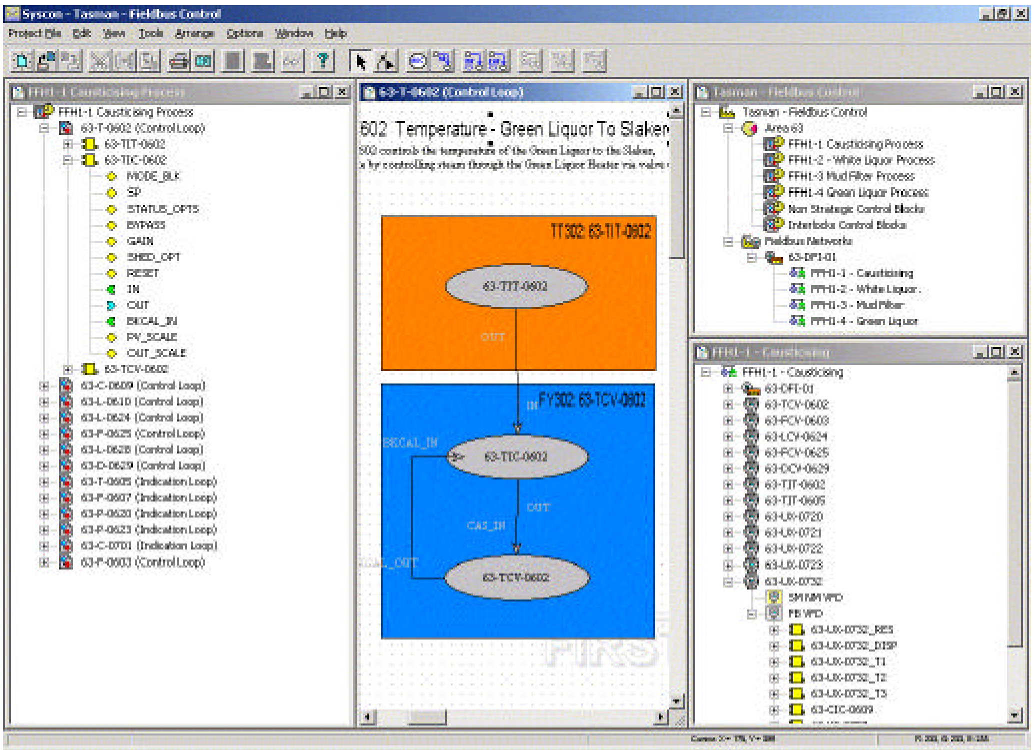

Figure 12 Fieldbus device and control strategy configuration

The parts of the old infi90 DCS that still exists and the Allen-Bradley PLC5 for the Motor Control Centers (MCC) integrate to the new host computers in the new system through OPC. The Fieldbus hardware also integrates with the process visualization software through OPC. Thus, OPC is the software backplane of the system allowing for advanced control and asset management software to be added in the future.

With all the basic controls in place, Tasman is now looking to add on the web-based AssetView online plant asset management package in order to fully benefit from the advanced diagnostics features on an enterprise-wide scale.

8. Conclusion

A second generation Fieldbus system shall support HSE (High Speed Ethernet), FFB (Flexible Function Block), MIO (Multiple Input/Output), and MVC (Multi-Variable Container) as well as dynamically instantiable function blocks. These technologies allow the system to be used in hybrid and batch applications without deviating from FOUNDATION™ Fieldbus.

9. References

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