PROFIBUS IN PROCESS CONTROLS

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Abstract

The cryogenic installations on the DESY campus are widely distributed. The liquid Helium (LHE) is produced in a central building. Three cryogenic plants are installed. One is in operation for FLASH the other two are currently in the commissioning phase and will be used for the European XFEL. Thousands of I/O channels are spread over the campus this way. The majority of the I/O devices are standard devices used in process control. The de facto standard for distributed I/O in process controls in Germany is Profibus. So it is obvious to use this bus also for cryogenic controls. Subsequently we developed also special electronics to attach temperature and level readouts to this field bus. Special diagnostic tools are available and permanently attached to the bus. Condition monitoring tools provide diagnostics which enable preventative maintenance planning. Specific tools were developed in Control System Studio (CSS) which is -the-standard tool for configuration, diagnostic and controls for all cryogenic plants. We will describe our experience over the last years with this infrastructure.

THE USAGE OF FIELD BUSES

Cryogenic installations for liquid Helium are typically widely distributed. Starting from one or more central helium liquefiers the helium is typically distributed on side by long transfer lines. All of the process I/O is installed along these lines.

It is obvious that the signals may not be connected directly to the process computer. The cable length would exceed technical limits for noise reduction or may cause grounding problems.

Starting with the HERA helium plant we introduced field buses for distributed I/O. Two decades ago we used SEDAC. SEDAC is an in-house standard at DESY. It may be used for distances as long as one kilometre. The disadvantage of an in-house solution is that there's no commercial support and any kind of signal conditioning must be developed and built in house.

In the 1990th it was decided that DESY cryogenic control should go more commercial. As a basis the CAN field bus was chosen. This provided access to various I/O modules with several different signal conditioning types including all of the basic types for process controls like: 4-20mA(in/out) and relays(in/out).

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The next level of signal conditioning came into play for the European XFEL. One basic decision was to make use of the state of the art intelligent I/O controllers like pressure transducers and valve positioners. New controllers provide intelligent local diagnostics which is useful e.g. for valve controllers. In addition they can be configured 'on the fly' through the filed-bus which us useful e.g. for pressure transducers – to change the operation range.

Two families of devices came into play: Devices for ProfiNet and those for Profibus. At that time it was not clear whether ProfiNet components would actually make their way into the I/O business or whether ProfiNet would more likely form the connection between PLCs and supervisory controls.

The decision in favour of Profibus proved to be the right one. Up to now no significant number of intelligent I/O devices found their way into the ProfiNet market.

CUSTOM PROFIBUS DEVICES

In cryogenic controls it is not sufficient to rely on the basic I/O signal conditioning. An additional family of cryogenic specific signals must be supported:

Low Temperature Readout

Temperatures below 10K are typically read out with special sensors. Small measurement currents help to avoid heating of the sensor itself. This introduces a high noise to signal ratio. Special custom readout electronics are necessary to achieve high accuracy and a good reproducibility.

Helium Level and Heater Control

Reading helium levels with a thin resistive wire is not an easy task. The measurement current must be high enough to run the wire into normal conductivity. On the other hand the current must be supervised to avoid damage when the vessel is empty or even under vacuum.

Fig. 1 shows the I/O modules which are connected by an internal CAN bus to the Profibus coupler.

Figure 1: Custom I/O: Low Temperature and Level- / Heater Control.

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CONFIGURATION

All Profibus I/O has a specific way how the data is represented in the Profibus address space. This kind of information is stored in so called GSD (Geräte Stamm Datei) files. Commercial configuration tools read theses GSD files in and provide the possible options to the user. The final configuration is written to system specific binary files. These files are used in PLCs or process controllers to map all of the Profibus nodes and their local I/O to the local address space.

In the DESY/ XFEL case we are using EPICS as our process control system and the operating system is VxWorks. It is obvious that the binary files will not work in this configuration. So we decided to create our own configuration tool which generates OS independent XML files. All of our configuration tools are developed as Eclipse plugins written in Java. They form the CSS (Control System Studio) toolkit together with all the applications in operation in the control room.

Hardware Layout

The CSS plugin is called I/O configurator and it acts in a similar way like the commercial configuration tools. It reads the GSD files and offers all of the possible Profibus devices to the user. By picking and combining the individual devices the user can configure a complete Profibus segment. Each segment is connected to an individual Profibus card in the EPICS IOC (Input Output Controller).

Software: The Epics Database

Similar to the Profibus configuration we developed a configuration tool for the so called EPICS 'databases'. These databases are ASCII files which specify the instantiation of records which in term define the processing and dataflow. The DCT (Database Creation Tool) supports the creation of hierarchical record structures. This helps defining record structures of the same kind.

SIMULATION

Wouldn't it be nice to test the control software before the equipment is installed in the field? We found this to be true and valuable. Being able to test the control software with simulated I/O is extremely useful in two cases:

Changing Existing Configurations

Following the requirement that the existing control software must be significantly modified, but the time for testing and commissioning is very limited, we decided to introduce a simulation system. The system simulates all Profibus devices on the Profibus segment. All signals provide the correct signal type and reasonable signal levels. The system is called WinMod and is running on PC hardware. It requires specific Profibus controller boards. The system is configured by an XML file. The file is also generated by the I/O configurator plugin. No specific configuration is necessary.

Following this approach it was possible to reduce the overall commissioning time significantly.

Testing New Configurations

The first steps for new systems are to check whether all of the signals are correctly configures. Second the control loops must be checked and third the state notation or sequence programs must be controlled.

All of these steps can be run through by means of a system which simulates the connected I/O. In this case the 'original' software on the IOC may be used without changes specific to the simulation mode. Depending on the steps which shall be run it will be necessary to add more functionality to the simulation system. This may also cover control loops or logic states of equipment.

OPERATION

Once a Profibus segment is in operation – it is running very stable. But it may take some time until this point is reached. Typical problems are: Cable end resistors which are not connected or at the wrong location; configuration of fibre optical link modules; configuration of nodes where the actual memory layout does not match the one configured in the Profibus master (here: the IOC).

The advantage of operating Profibus I/O is the predictable update rate which is constant and can be calculated based on the bus parameters. This can be taken into account for control loops. The process engineer must be aware of the fact that equipment behind a DP/ PA gateway is updated at a lower (fixed) rate.

Existing XFEL Profibus Networks

The Profibus networks are separated into segments. This is designed based on logical units (signals grouped for one subsystem) and/ or technical specs (the number of nodes and bytes supported in a Profibus segment).See Table 1. The number of devices is typically a factor of 10 higher than the number of nodes. The number of individual signals is another factor of ten higher.

Table 1: XFEL Profibus Segments and Nodes

System	Segments	Nodes
AMTF	7	310
XFEL Linac	13	~500

REDUNDANCY

Cryogenic systems are typically operated in 24/7 mode. This requires special precaution for the layout of the whole system [1] including:

- Cryogenic Hardware
- Process Controller
- Computer Networks
- Field Buses
- Electric Power

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Redundancy should be introduced wherever reasonable and adequate. E.g. redundant temperature sensors are adequate redundant flow meters aren't.

Redundant Profibus Links

The backbone Profibus link within the cryogenic building consists of multimode fibre optic cables and the associated OLMs. The topology forms a ring. This setup guarantees continuous operation even with one damaged connection in the backbone. To span the distances in the XFEL tunnel it is required to use single mode fibre. Again we will establish a ring topology to avoid single points of failure in the backbone link.

Redundancy in DP/ PA Gateways

Profibus equipment connected to the PA gateways is powered by the gateway through the Profibus cable. This adds a critical functionality to the gateway power supplies. Therefore theses power supplies a typically redundant throughout the system.

Redundant Process Controller

Besides redundant power supplies attached to redundant UPS systems we also introduce redundant process controllers for all critical cryogenic components.

This adds a certain level of complexity to the system because Profibus does not support such an approach 'out of the box'. Two aspects are obvious: Profibus does not support multiple master systems. In addition it is not supported to switch mastership between nodes with different Profibus IDs. As a result this would cause the whole bus to run a reset/ restart sequence.

To overcome these problems a new firmware for the Profibus cards in the process controllers was necessary. In this case the firmware is provided by the company Softing which also produces the cPCI (Compact PCI) Profibus cards.

DIAGNOSTICS

Several levels of diagnostic tools are available for Profibus from the supervisory channels in the control system down to the hardware level.

Diagnostic Channel in EPICS

Each Profibus node and each OLM is identified by a logical channel in the process control system (EPICS). Each channel defines the health state of one of these nodes. The channels are displayed on synoptic displays used by operators and the on call shift.

Diagnostic Equipment on the Profibus

Special diagnostic equipment on the Profibus can be directly attached to Ethernet. The online status information of the Profibus segment is displayed on individual web pages (see Fig. 2). The Ethernet connection is typically routed to the diagnostic network to stay off the production network with diagnostic traffic.

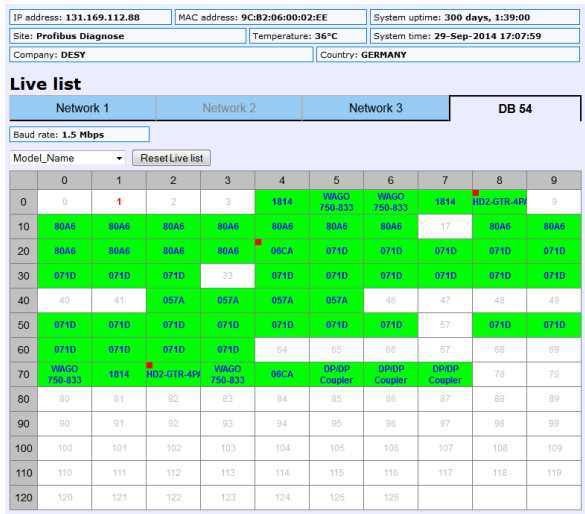

Figure 2: Online Profibus diagnostic web pages

Hardware Diagnostics

In addition to the online information on web pages it is possible to connect diagnostic equipment directly onto the Profibus cable. This allows dedicated diagnostics on the signal level on the protocol level. The Profibus segments at DESY are prepared to provide Profibus connectors for this purpose.

CONCLUSION

Profibus has become a stable and reliable 'partner' at DESY for the cryogenic control system. It is used for all current cryogenic projects for about a decade. Special firmware in the Profibus cards is mandatory for redundant process controllers. Permanent online diagnostic tools help to identify problems on the fly.

REFERENCES

[1] T.Böckmann, "Profibus bei 2 Kelvin – Supraleitung für die Forschung mit Photonen", PI Conference, March 2013

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