Application News

Industrial Communication
Partner Information

2010 – 003

Softing's PROFIBUS Solution operates in a Redundant Process Control System that Manages a Helium Cooling System at DESY

For more than 20 years Germany's largest helium cooling system operated reliably with a traditional centralized process control system. Rising maintenance costs for this aging system lead to the decision to modernize the system with a process control concept that relies on a decentralized I/O system over PROFIBUS and on a high-availability concept based on system redundancy. Softing's enhanced PROFIBUS protocol software provided the foundation for achieving the redundancy concept with PROFIBUS by guaranteeing an instantaneous and bump-less switchover of all connected I/O devices.

About 50 years ago, DESY (Deutsches Elektronen-SYnchrotron) was established on December 18, 1959 with the signing of the State Treaty between the City of Hamburg and the Federal Republic of Germany. The founding father and first director, Professor Willibald Jentschke, wanted to set up a competitive particle accelerator to take an active part in the upcoming research field of particle physics. In 1964, the first accelerator, which incidentally also gave the research center its name Deutsches Elektronen-Synchrotron, took up operation. The DESY accelerator, the largest one at its time, was followed by the storage rings DORIS in 1974, PETRA in 1978, and HERA in 1990. All these accelerators were used for the thorough investigation of the innermost structure of matter by measuring subatomic particle collisions in detectors, some as big as a house. Researchers working on PETRA detected the gluon, the "glue" particle that transmits the strong force between quarks and holds these elementary particles together, and HERA accurately resolved the complicated structure of the proton. These insights are now standard material for physics textbooks and will help in the analysis of data taken during experiments like the Large Hadron Collider LHC at CERN.

Particle scientists are trying to pry more and more secrets from nature by substantially increasing the energy level of particles through speeding them up and then smashing them together. Sounds like fun! However, accelerating particles requires two ingredients. First, you need lots of power and second, you need superconducting accelerator components that operate at a temperature that is very close to absolute zero degrees Kelvin. These cryogenic temperatures are attained in Germany's largest refrigeration plant that was built in the mid-80's. This cryogenic plant continually produces liquid helium at 4.3o Kelvin to cool the super-conducting electromagnets. In the past, this cryogenic facility provided the cooling agents for the 6.3 kilometer (about 4 miles) spanning HERA accelerator ring. Today, the facility efficiently produces liquid Helium for an x-ray laser project that has even lower temperature needs of 1.8 Kelvin.

Cooling plant with helium reservoirs

Industry
- Research institute
- Particle colliders
- X-ray lasers

Task / Objective
- Retrofit of the redundant control system for DESY's helium cooling system

Requirements
- Operation for at least another 10 years
- Improvement of reliability and availability of the cooling system
- Bump-less redundancy switchover
- Reduction of maintenance cost

Solution
- Softing PROFIBUS interface card
- PROFIBUS API for redundant master

Benefits
- High availability of the system
- Components can be replaced during operation
- Control system and PROFIBUS drivers are freely available as open source

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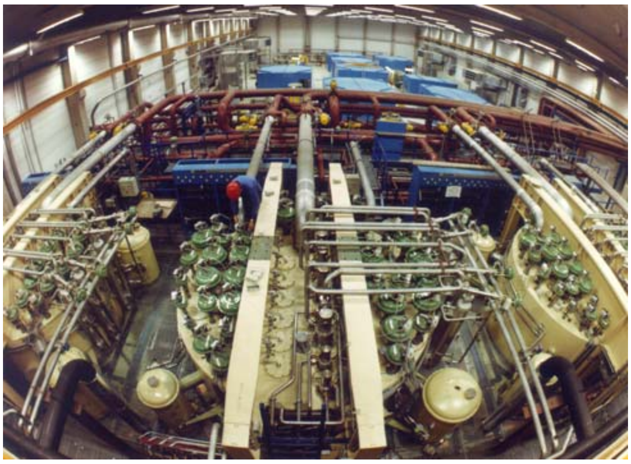
Some Numbers


Inside view of the cooling plant

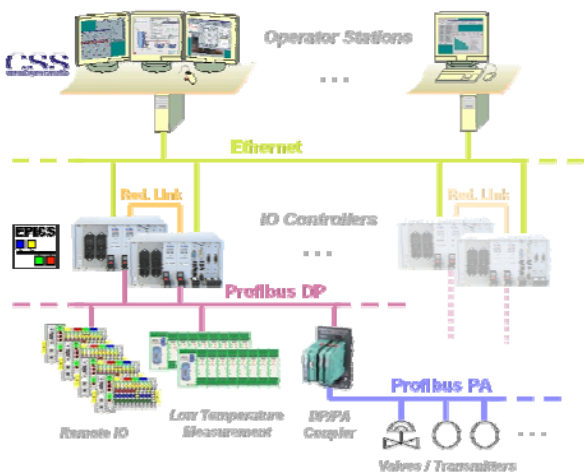
Building 54 in the DESY complex contains the heart of the cryogenic operation. Three identical sub-systems compress gaseous Helium to about 16 bars (232 pounds per square inch) and convert it into liquid Helium following a controlled de-compression procedure. Basically, the gas runs from tall and extremely well insulated cold boxes to 7 de-compression turbines. At the end of its journey the Helium is liquefied and is injected into the distribution system at 4 bars of pressure. More than 15 metric tons (about 33,000 pounds) of liquid helium are circulating through the system at any moment.

The process control system is connected to approximately 1000 monitoring locations and handles more than 2000 data points collected from subsystems and 800 valves to operate the plant. Every second, hundreds of control loops crunch more than 6000 process signals.

Today, after retiring the HERA accelerator, the cryogenic plant is primarily used to cool the linear accelerators used in photon experiments. In the near future, the cryogenic system will cool the 3.4 km (2.11 miles) European X-Ray Laser Project (XFEL) that is currently under construction. When finished in 2014, this laser will provide the world's brightest x-ray beam.

Modernizing the Control Technology

The refrigeration facility had operated continuously for more than two decades. After all these years many components of the control system were displaying wear and tear. In particular, several components of the central I/O system had reached and exceeded their life expectancy. For example, after 20 years of continuous operation at 4 Hz, some reed relays, used to condition analog inputs, had become a burden to maintain. In addition, corrosion in some long cables had increasingly caused problems in potential equalization. It was obvious that it had become necessary to modernize the aging process control system. After evaluating alternatives to replace the aging I/O system, the control engineers of DESY decided on PROFIBUS, mainly due to the large number of commercially available devices. An additional advantage of PROFIBUS was the availability of fiber optic components to span long distances without adverse effects to the signal quality. Pressure transmitters and valve controls would be able to connect to PROFIBUS via a DP/PA coupler while the cryogenic temperature transmitters (developed at DESY) and additional analog and digital devices would be able to connect to PROFIBUS via a remote I/O link.



Control system overview

Modern compact PCI systems replace the original process control system that was based on VME and multi-bus controllers. The advantage of the new system includes lower power consumption and fan-less controllers that significantly reduce the risk of system failure caused by overheating.

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The controller and the control software received a face-lift, too. The new system consists of redundant I/O controllers (IOCs) running VxWorks as the operating system and EPICS as the control software executing all time critical control algorithms. EPICS is an open-source control software package that has been significantly enhanced by DESY engineers to fit their process control requirements. EPICS is mainly used within the science community but is freely available for anyone. (http://epics.desy.de). The Control System Studio (CSS) (http://css.desy.de) is another free software package for system operators that manage the cooling process and for control engineers to configure the PROFIBUS networks and the process databases.

Redundancy Concept for High-availability

At DESY, scientific advances depend on the flawless operation of the cryogenic system. Once a cooling system fails it takes a significant amount of time to regain the conditions necessary for the scientific experiments. In order to minimize the potential for such a system failure parts of the new control system are based on a redundancy concept. In addition, the cryogenic system consists of three separate refrigeration units and has, as an extra precaution, a backup reservoir of 2.5 metric tons of liquid helium.

All controllers are connected via redundant Ethernet switches. Furthermore, each controller station consists of two redundant IOCs that control the I/O devices over the fiber optic PROFIBUS ring. The fiber optic ring is designed to tolerate a system failure in one segment. The actual process periphery does not follow the redundancy concept. However, every I/O device is powered by a redundant UPS.

The redundant IOCs are at the core of the high-availability concept. All IOCs are paired as a primary or active controller and a secondary or standby controller. Each controller has two Ethernet ports and two power supplies that are connected to two independent power sources. One Ethernet port connects the IOC with the I/O devices while the other port is used to continually synchronize the internal state and process image between the primary and secondary controller. This ensures a bump-less transfer of the system control to the secondary controller in case a key component within the primary fails.

PROFIBUS on Hot-Standby

A bump-less transfer of connected PROFIBUS I/O devices from the primary to the secondary IOC is somewhat tricky due to the nature of the network protocol. The solution has to include the immediate transfer of the PROFIBUS master address from the primary to the secondary IOC to guarantee an uninterrupted continuation of the data exchange with the periphery. Standard PROFIBUS implementations do not support this requirement because the start-up sequence of a PROFIBUS master includes the parameterization of all I/O devices. In our case this re-parameterization, as fast as it takes place, would still disrupt the control cycle or, in other words, would lead to a temporary loss of control over the process (which is a bad idea considering the dangers involved handling liquid helium).

Profibus interface

Softing's unique experience in implementing enhanced PROFIBUS protocol stacks that support bus-redundancy proved to be the key to satisfy this requirement. Softing modified one of its PROFIBUS interface boards to permit a complete initialization of the master stack on the secondary IOC without becoming active on the I/O network. The PROFIBUS I/O image is continually synchronized via the redundancy link between the primary and secondary IOC.

The final challenge for the secondary PROFIBUS master is to evaluate the health of the primary master. For this reason, the secondary master joins the network with a temporary address to exchange test frames between the primary and secondary master. In case of a change-over the pre-configured secondary master immediately assumes the address of the primary master and resumes the data exchange with the periphery. This abrupt change-over is completely transparent to all connected I/O devices.

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Where we are today

Matthias Clausen, director of Cryogenic Controls at DESY states the following:

Our high-availability system design ensures the necessary reliability needed for operating our cryogenic system. The redundancy concept guarantees the continuous operation in case of CPU or memory failures. Moreover, the new system design tolerates the replacement of components during operation. The successful integration of PROFIBUS into our EPICS system demonstrated again the importance of choosing the right technological partner.

It was the excellent cooperation with Softing's team of experts that kept us on track with our tight project schedule. We highly value Softing's outstanding support during the definition phase of our redundancy concept and during the software port to VxWorks. We are very happy that Softing agreed to release the source code of the jointly developed software driver to the EPICS collaboration suite.

Matthias Clausen, DESY

As of today, about one-third of our facility has been upgraded to the new control system and all tests are very successful. Very soon we will resume full operation with a state-of-the-art control system that efficiently cools our FLASH-Laser. After completing our system upgrade we are ready for our upcoming X-Ray Laser Science Project (XFEL)."

About Softing

In industrial automation, Softing is a specialist for fieldbus technology and has established itself as a world-leading partner for networking automation systems and control solutions. Softing provides customers the key technology to connect devices, controls and systems with the leading communication technologies. In fieldbus technology, Softing is a world-class expert for Foundation fieldbus, PROFIBUS, and CAN/CANopen/DeviceNet. The company's wide range of expertise includes solutions for OPC, FDT, and Real-Time-Ethernet protocols such as, PROFINET IO, EtherNet/IP, or Modbus/TCP. Many of the products and services developed by Softing since the company was founded in 1979 have become reference standards throughout the world. In addition, Softing has established itself as a provider of sophisticated diagnostic tools for fieldbus systems.

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