CRYOGENIC CONTROLS AT HERA

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Abstract

The 6.3 km proton storage ring of the HERA project at DESY will contain 422 superconducting dipole and 224 quadrupole magnets. Three refrigerators produce supercritical helium, which is fed into two transfer-lines that supply the superconducting magnets in the individual sections of the ring through 16 cryogenic boxes. Refrigerators and boxes are controlled by the distributed cryogenic control system. In addition, the magnet test facility, the superconducting cavities of the electron ring and the superconducting coil of the ZEUS experiment at HERA are all fed by the central refrigerator and controlled by the common cryogenic controls. This paper will describe the principles of the control system and show special solutions for the individual tasks.

Process Control for Cryogenic Systems at DESY

Historical Background

In 1970 the age of cryogenics began at DESY with the installation of the PLUTO experiment. As one of the first experiments worldwide PLUTO was equipped with a superconducting coil. The controls for the cryogenic equipment were fairly simple. Many valves had to be operated manually and only a few control loops were installed.

The next experiment with a superconducting coil at DESY was CELLO. Instead of the expansion compressors used in PLUTO it was equipped with cryogenic expansion turbines. The controls had to be more sophisticated. Using computers (LSI-11) for controls failed due to improper signal conditioning such as ground loops, etc.

Thererfore, while the next cryo plant was being installed in order to feed the magnet test stands for HERA magnet development, further computer tests for cryogenic-process-control were conducted. While the control system was made in-house, the plant itself was already equipped with PLCs for sending alarms and with interlocks.

The cryogenic plant for HERA

By the end of 1983, the layout phase for the central cryogenic plant for HERA had begun [1]. It was obvious that this plant had to be completely controlled by means of a computer control system. The experience of the previous cryogenic plants led to the requirements which were specified for HERA. Reliability, safe signal conditioning, easy-to-use software tools, distributed systems and availability within one and a half years were all stipulated.

The idea to build such a system at DESY was disgarded very soon due to the fact that neither the hardware nor the software were available at DESY. When we looked at the market for control systems, it was obvious that what we needed was a commercial distributed process control system. The one selected was the D/3 system from Texas Instruments [2].

It has all the desired properties (Fig. 1). The backbone of this system is a redundant communication link. The process computers (PCMs) are multibus-based 8086/87 or 80386 CPUs which can also be redundant. Redundant CPUs are installed for the cryogenic plant because of the long recovery times that are necessary even after short shutdowns.

On the same redundant link, we have PDP 11/73 display computers (DCMs) which drive the operator consoles. A VAX 750 is used for program development and data logging.

Cryogenic controls for the HERA ring

All cryogenic control decisions are made by the cryogenic control system computer which sits at a location well removed from the cryogenic components in the tunnel. The PCM performs extensive cryogenic control calculations and needs to know the most current values of all sensor devices, and needs to get the results of its calculations to the control modules, such as analog and digital values controlling helium flow. But the PCM cannot talk directly to the line on which these sensors and control modules sit. It must interface with an intermediary, which we will now describe.

All of the sensors and control devices operate through communications on the SEDAC (SErial Data ACquisition) bus system developed at DESY [3], whereby all data on a particular SEDAC line are made to flow along a single 50 ohm coaxial cable. The intermediary micro and supporting hardware operate on another in-house bus system, PADAC (PArallel Data ACquisition).

Device control and sensor readout along the SEDAC line are effected by special write or read SEDAC telegrams, which originate not from the PCM computer, but from the PADAC microprocessor.

Therefore, we must make the PCM computer talk to the PADAC microprocessor. The PCM is a commercial computer with its own networking protocol, and interacts over a special interface card (INTEL-ISBC544 card), so that PADAC must also communicate with this card. Now that the chain of hardware is established, we must develop a viable scheme for the ultimate data transfer: PCM - PADAC - SEDAC.

PCM and PADAC share a common buffer on the 544 card. This buffer contains all of the 16 bit words of information regarding the cryogenic sensors on the SEDAC line. The format for this buffer is an integral part of the system and is established in the local database used by the PADAC microprocessor. All input data on the SEDAC line are continually being read with polling rates on the order of a few seconds. They are converted when necessary (most of the sensors do not measure data in exactly the form PCM expects) and placed into the common buffer. The output data are placed by the PCM computer into the common buffer and then transmitted to SEDAC. Input and output data for the PID control loops need to be synchronized. This is accomplished via a Common Pulse (CP) transmitted to all SEDAC devices simultaneously every 1.25 [sec]. This ensures that all SEDAC action occurs at specific times, thereby allowing accurate differential calculations.

Offline Database

Our control system is distributed over a variety of processors. They all need a consistent picture of the real process so that they can smoothly work together. We therefore decided to setup a relational database in our VAX which contains all relevant information on cableing, addressing schemes, memory layout and conversion curves for the HERA cryogenic system.

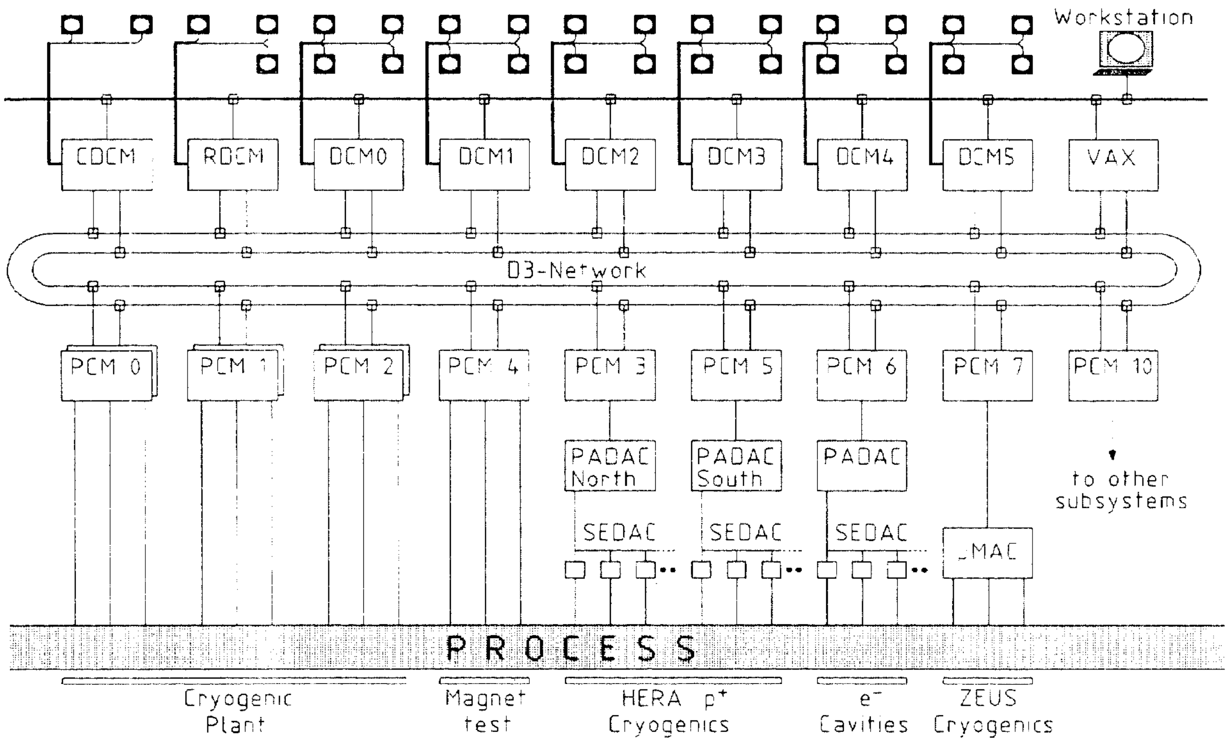

Fig. 1: The cryogenic control system at DESY

The advantage of a relational database over other database types is that we can define almost independent tables for the different processors. The only common entry in these tables is the so-called IO-name which identifies individual devices like sensors or valves.

In detail our database contains tables for

- the control loops being performed in the PCMs
- memory layout of the dual ported ram of Intel-544-board and PADAC
- SEDAC addresses
- conversion tables to be used by PADAC to supply PCM and SEDAC with data in correct format
- cableing.

The fact that the database contents are split up into several tables makes it easy to write programs for users with specific needs. This again helps to keep the database up to date. There are programs for technicians who are responsable for cableing and others for engineers who have to define control loops for the cryogenic process.

In the latter case the database also helps to make use of the symmetry of the HERA cyogenic system which consists of eight almost identical octants. We have tables with information common to all octants and others with data specific for each octant.

The conception and realization of our database was tested successfully this spring when the database system was used to extend the control system for the superconducting cavities for the HERA electron ring. Within 4 months a visiting scientist was able to do this job with minimal support.

Other cryogenic components at DESY

Since the existing control system proved to be reliable as well as easy to maintain and operate, other groups at DESY installing cryogenic equipment also wanted to be integrated into in the cryogenic control system.

Superconducting cavities for the HERA Electron ring

The eight superconducting cavities [4] are installed near by the central helium refrigerator in the HERA tunnel. They are fed by a transfer-line connected to the main transfer-line to the cryogenic plant. The expertise of the cryogenic operators, coupled with the necessity of communication between refrigerator- and cavity controls, led to the incorporation of the whole cryogenic cavity control into the existing cryogenic control system. (Fig. 1) Process data are taken by means of the SEDAC/PADAC system already used for cryogenic ring controls. Additional operator consoles in the cryogenic control room enable permanent operator service for the cavities.

The superconducting coil of the ZEUS experiment

Along with the cavities, the superconducting coil of the ZEUS experiment is fed with liquid helium by the central liquefier. Data acquisition is performed by a local processor handling analog and digital input and output. In addition, this processor has to convert temperatures from millivolts into Kelvins read by sillicon diodes.
This processor (μMAC) will be connected with one of the process computers over a RS232 link running the same

standardized block transfer protocol like between PADAC and PCM.

Current Developments

X-Window Terminals

Presently DESY is implementing a new software tool. The main idea is to port the entire display capability of a D/3 console into the DEC-Window environment. This feature enables cryo operators to use any (so far - DEC-)workstation on the DESY site. The software can also be run on PCs and several X-Window terminals supporting DEC-Windows.
The main advantage of this development is the freedom to use screens other than the original D/3 ones for controls. This feature might have an impact on future developments at DESY. In the near future this tool will be used by ZEUS operators to monitor their cryogenic equipment. In addition to cryogenic operations from the cryo control room, it will be possible to check remotely the cryogenic behavior of the superconducting cavities without the necessity of extending the D/3 highway, but instead by merely using a (DEC)-Window capable terminal on the DESY-wide Ethernet.

HERA Communications

Communications between cryogenic controls and other systems like the HERA proton vacuum control will use TCP/IP as the software protocol based on Ethernet hardware. Displays created by proton vacuum and cryogenic controls will be exchangable since both displays are in the X-Window environment.

The communication with HERA accelerator controls is a task that has to be completed in the near future. Developments will be implemented based on data exchange over TCP/IP protocols. Another task is the continuing development of diagnostic tools both for operations and maintenance.

References

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