A Control System based on Industrial Components for Measuring and Testing the Prototype Magnets for LHC

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Abstract

A test bench has been built at CERN to test and measure the prototype superconducting magnets of the future LHC. The control of this test bench is made by means of industrial components. The process control uses standards PLCs connected by an ethernet plant network. A supervisory software system carries out the man-process interface, the data collection and the remote access. Most of the process control software was included with the equipment whilst its integration and the supervision has been made at CERN.

1. Introduction

All around the 26.7 km circumference of the future Large Hadron Collider (LHC), more than 1500 twin-aperture superconducting magnets will be installed and will operate at a temperature of 1.8 K. These magnets will be manufactured by the industry and then tested at CERN. Two successive test phases will allow measuring first the magnets individually then clustered in a string. A prototype of a magnet test bench has been built and is used for the first magnet prototypes. More benches will be built in order to measure up to twenty magnets simultaneously.

Rather than developing the process control system in-house, it was decided to use industrial control systems components. Industrial control systems are based on off-the-shelf components and equip all modern industrial installations.

2. The processes involved in the test bench

Three main components set up the cryogenic system[9]:

1.The Cooldown and Warmup Unit (CWU) delivers 120kW of refrigeration. It thus allows cooling down and warming up a 17000kg magnet in one day keeping a maximum temperature difference of 50 K between the inlet and outlet of the magnet.

2.The Magnet Feed Box (MFB) supplies the magnet with the required cryogenic fluids and electrical power during the operation. It has a built-in heat exchanger to handle the latest phase of the cooldown (4.2K to 1.8K). Safety functions have been implemented to prevent damages during the quenches. The MFB control is made of PID regulations attached to a main program aimed to manage the different phases of the operation.

3.The Warm Pumping Unit is used to pump the 1.8 K saturated helium bath of the MFB. It is the final stage of the cold pumping line and has a capacity ranging from 6 g/s @ 1kPa to 18 g/s @ 3 kPa. The WPU's control defines the start up sequences of the different pumps.

Other utilities intended to carry out the transfer of the cryogenic fluids complete the cryogenic system.

The following processes complete the test setup:

- A measuring device. The magnetic measurements are made with a probe attached to the end of a 11m rod which itself is moved by an automatic sledge. The sledge displaces the probe inside both magnet's aperture with a precision of 0.1mm[7].
- A Demineralized Water Unit (DWU).
- An electrical power distribution system.
- A set of gauges. Around 100 gauges are located on the magnet and in the cryostat. Their values provide the status of the magnet.

3. The Approach

The test bench components manufactured by industry were specified to include their process control hardware and software. This approach ensured that the responsibility for the correct handling of the process stayed with the equipment supplier. Industrial process automation systems were specified[2].

Being the project manager, CERN had to set up the integration of the different components. This could be done by means of a common plant network.

CERN specified all the parameters which intervened in the integration and supervision. It was stated in the specification that the usage of a particular brand of PLC and the proprietary network was preferred.

Supervisory control and monitoring systems would be located in the bench control room. The requirements were the same than the classical industrial supervision requirements: graphical monitoring of the process, real-time trending, alarm management and archiving. Industrial supervisory package fulfill all these needs and are designed to manage industrial process control components and to communicate with them.

4. The Process Control

4.1 PLCs

Each process is controlled by a local programmable logic controller (PLC). Most of the processes involved use intensive PID control which are traditionally handled by distributed control systems (DCS). Nowadays, PLCs may include PID regulation. Therefore the PLCs were used both for continuous and sequential process control.

PLCs are standard automation controllers made for the industry. They are known for their robustness and reliability and are generally easy to configure and to maintain. A high degree of modularity and numerous specific modules (I/O cards, positioning modules, ...) allow configuration of an architecture close to that required.

4.2 *Integration*

With PLCs, the process control architecture is distributed. By choosing PLCs it was possible to divide the process into small functional entities which are controlled locally.

Depending on the component, the process control software was either included with the component supply or has been developed at CERN. To ease the integration of all the parts, a unique brand of PLC was recommended[1].

An ethernet plant network links together the PLCs and give access to the upper levels of the control system[2].

The whole amount of inputs and outputs between the processes and the two benches which make the first test prototype reaches 1500. Ten PLCs are used. Every second, nearly 2000 values are transferred to the supervisory system.

5. Supervision

Most of the commercial supervisory packages run on PC compatible computers. Some of them have UNIX Workstations implementations. The bench's complexity, the CERN's commitment toward open systems and the need to communicate between several supervisory systems drove us to choose a UNIX based software[1]. We use a supervisory system called FactoryLink™ on HP workstations.

Industrial supervisory systems sit above PLCs. Their aim is to supervise the process. The core of supervisory systems is a real-time database containing relevant data coming from the process. They offer such facilities as man/process interface via synoptics, alarm management, real-time and historical trending, process sequencing using recipes and database logging. For each process a specific supervisory application has been developed. The whole system manages 90 different windows, 700 alarms and 140 trend curves.

Three workstations connected to the plant network are located in the control room. They communicate with each other and with remote computers via TCP/IP across ethernet. Supplemental displays are available by means of X terminals.

One of the workstations is used to centralized all the archives. Customized archives are available for each application. The frequency of data storage changes depending on the operation's phase. In average, 700 values are permanently archived with a frequency ranging from 5 seconds to 1 minute.

From the beginning it was decided not to include the supervisory system in the security loops. A workstation failure should not jeopardize the security system.

Whilst the PLC's prices are attractive, the supervisory system is relatively expensive. Each workstation needs a license which itself is rather costly. This is compensated by the great wealth of facilities offered by the supervisory system.

The price of all the control system, including hardware and software for the process control, the communication and the supervision, is in the order of 700 SF per I/O channel.

6. Man - Process Interface

The man-process interface developed on the supervisory system is highly graphical. We used intensively the point and click method.

A uniform look is used for all the processes and simplify the learning for the operators. Each process is seen through a main synoptic. Standardized symbols are used to display the process elements (valves, gauges, ...)[6]. Pointing on an element brings up a specific window to interact with this element. Number and origins of present alarms are shown on each screen

From the main synoptic it is possible to open a display containing curves which represent the trends of the process values.

7. Remote connections

There was a demand for accessing the data from remote computers, either to visualize the ongoing process or to do some analysis on the archives. Several programs have been developed or bought to fulfill these requirements.

7.1 *Access from a PC*

The goal was to make the access totally transparent. The user should be able to open archive files as if they were on their PC and should have the capacity of developing applications with standard PC software.

A client-server connection software has been developed and creates a DDE link between common PC software (Excel, Visual Basic, ...) and the supervisor. Thus the data may be shown in spreadsheets or used in any PC program which are DDE compliant.

HP NetWare™ program makes the supervisory workstation behave like a Novell server. Thus, the PC accesses directly the archive files formatted in such a way that they are compatible with common software.

This set of tools allows multiplying the number of graphical displays without additional cost.

7.2 *Access from an X terminal or a UNIX system*

The commitment of FactoryLink™, the chosen supervisory package, to open systems makes this access straightforward.

FactoryLink™ is X11 compliant. The graphical interface can directly be used on a remote computer or X terminal.

NFS gives simple and transparent access to the archives.

7.3 *From any system*

A text based interface, developed at CERN, allows interaction with the process. It is mainly used when connected from home or on ASCII terminals.

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[1] Siemens

[2] The protocol used is Siemens Sinec H1™. It is OSI compliant[3].

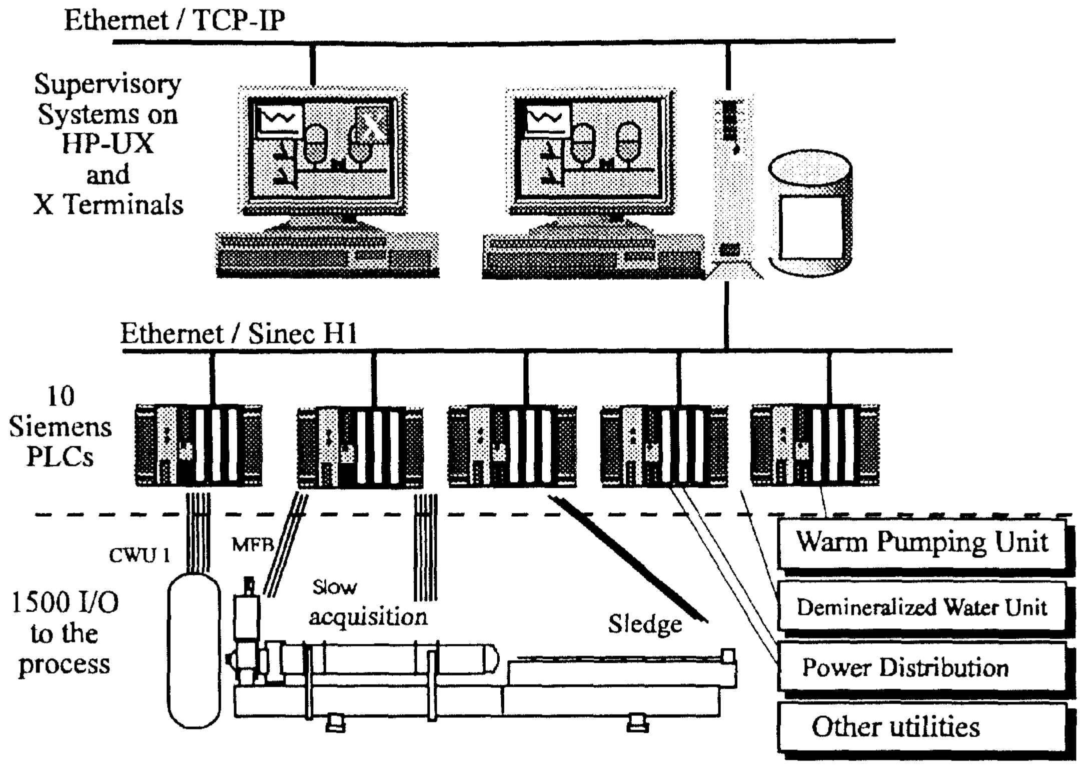

Figure 1. The control system architecture

8. Conclusion

The choice of PLCs allowed development by the industry of the process control software. CERN and industry shared the same approach. Experience showed us that great attention should be drawn to the operational specifications which should include a precise acceptance procedure. Lack of rigor leads to repetitive iterations with the external company which wrote the software.

Following our recommendation, nearly all the suppliers chose the same brand of PLC. It was thus very easy to integrate all the components in a single ethernet plant network. The modularity of the PLCs eased a lot the hardware maintenance and the stock management. The control system's structure offers a high level of reliability and security.

The supervisory applications were rather simple to develop and to tune with the chosen supervisory package. The users have particularly appreciated the MMI's comfort and the archiving capabilities. The supervisory system proved to be stable but the workstations' load was surprisingly greater than expected.

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