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NEW LONG-TERM HISTORICAL DATA RECORDING AND FAILURE ANALYSIS SYSTEM FOR THE CERN CRYOPLANTS

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ABSTRACT

CERN uses several liquid helium cryoplants (total of 21) for cooling large variety of superconducting devices namely: accelerating cavities, magnets for accelerators and particle detectors. The cryoplants are remotely operated from several control rooms using industrial standard supervision systems, which allows the instant display of all plant data and the trends, over several days, for the most important signals. The monitoring of the cryoplant performance during transient conditions and normal operation over several months asks for a long-term recording of all plant parameters. An historical data recording system has been developed, which collects data from all cryoplants, stores them in a centralized database over a period of one year and allows an user-friendly graphical visualization. In particular, a novel tool was developed for debugging causes of plant failures by comparing selected reference data with the simultaneous evolution of all plant data. The paper describes the new system, already in operation with 11 cryoplants.

1. INTRODUCTION

At CERN in total 21 Helium cryoplants are operated, ranging from 400 W to 18 kW cooling power at 4.5 K entropy equivalent. Six refrigerators (4 x 18 kW at 4.5 K and 2 x 400 Watt at 4.5 K) are used to cool the superconducting cavities and magnets of the Large Electron Positron collider (LEP) and Super Proton Synchrotron (SPS). The other 15 Helium liquefiers supply superconducting magnets of various LEP and SPS experiments [1] as well as large cryogenic test facilities for the new Large Hadron Collider (LHC) [2]. All installations are fully automated and remote controlled from dedicated control rooms (in total 5). Table 1 shows an overview of the presently operated Helium cryogenics for experiments and test facilities. For each plant the number of analog and digital process signals to be controlled and monitored is given.

Table 1: Overview of presently operated Helium cryogenics for experiments and test facilities

USER	Helium Plant	Analog I/O's	Digital I/O's
LEP, PA4 (ALEPH solenoid, quadrupoles)	Sulzer TCF200 + Linde Purifier + Bauer recovery compressor + 3000 m^3 He pure & impure storage	230	580
LEP, PA8 (DELPHI solenoid, quadrupoles)	Sulzer TCF200 + Linde Purifier + Bauer recovery compressor + 3000 m^3 He pure & impure storage	240	640
NA 49.1 (Vertex)	CNA 100	140	285
NA49.2 (Vertex)	CNA 100	140	285
NA-ATLAS/H8	CNA 100	140	285
NA-CMS/RD5	CNA 100	120	260
NA-COMPASS	CNA 100	120	260
NA-LHC/Bl.4 Test Facility	CNA 100	130	320
SM18 LHC Test Facility	6 kW Air Liquide	530	650
SM18 LHC Test Facility	6 kW Linde	300	540
Cryolab LHC Cable Test Facility	Sulzer TCF50	350	660
Cryolab Dewar Filling Station	Sulzer TCF50	150	280
SM18 He Gas Recovery	2 Linde purifers+3 Sulzer Burckhardt recovery compressors +15000 m^3 He pure & impure storage	70	400
Cryolab & NA Gas Recovery	2 Linde purifers + 3 Sulzer Burckhardt recovery compressors + 35000 m^3 He pure & impure storage	140	360
	Total:	**2800**	**5805**

For the control and short term monitoring of all the cryoplants in operation a industrial standard supervisory system from ASEA Brown Boveri (ABB) [3] is used. The normal operation of the cryogenic installation during a continuous period of 9-11 month, with relatively slow (over 2-3 weeks) transient conditions, demands for a long term historical data acquisition system. Archiving several 100 megabytes of process data, which are accumulated from each installation listed in table 1 over 12 month and keeping it in one centralized database, exceeds the capacity of the ABB supervisory system. Therefore a special adapted data acquisition system was developed, based on two DEC workstations running a self-written software package. The DEC system reads out every 8-15 minutes all process data, event and alarm lists from the various decentralized ABB control systems, stores the information in one central database and provides two user-friendly operator interfaces to display the data. In addition to a World Wide WEB interface, a special tool for failure analysis was developed to allow backward and forward display of all data by the same animated graphical representation used for monitoring of the normal operation.

2. ORGANISATION OF THE CRYO CONTROL AND DATA ACQUISITION SYSTEM

2.1 The cryogenic process control and supervisory system

The ABB supervisory system contains three standardized components to provide a de-centralized control of the cryogenic plants:

The so called Master Piece unit (MP) connect the system to the real process by exchanging digital and analog I/O signals and stores them in its process database. It contains also complete programmable logic controllers (PLC's) for the control of machines and processes. The MP executes the control logic with cycle times down to 20 msec and stores the last 200 process alarms or events in a dedicated memory area. The MP contains also 4 storage files (logs), each with room for 10 analog process variables, to do the short-term trending of the most important plant parameters (max. time period: 240 h, min. sample rate: 15 sec)[4].

The Master View unit (MV) is responsible for the man-machine communication using color graphic video display terminals and printers. The MV station displays the cryoplant status and allows manual control of the installation, using animated process (max. 86), object (max. 2600) and trend displays (max. 20). It provides also the alarm- and event list handling from all the MPs connected to it.[3]

The Master View station communicates with it's subordinated Master Piece unit(s) over a multidrop, master-slave bus called Master Bus 200 (MB). The max. communication speed of this asynchronous bus, complying with the RS 422 standard, is 153.5 kbit/sec. Figure 1 shows a typical example of such a widely distributed system structure, used to control and monitor the cryogenic installations of the North Area and LEP section from one dedicated cryo control room. There are in total 3 MV units, each configured as master. The first MV station is assigned to the North Area experiment cryogenics and controls via 9 MP units, all connected in parallel and configured as slaves, the compressors, cold boxes and infrastructure of the cryogenics for SPS fixed-target experiments. A second MV unit is dedicated for the cryogenics of the two LEP experiments ALEPH (Apparatus for Lepton Physics) and DELPHI (Detector with Lepton, Photon and Hadron Identification). Both installations are located far away from the cryo control room (ALEPH 15 km, DELPHI 10 km) and therefore apart from the two MP units a second MV station situated in a small local control room has been added to each network. The local control room is used only during maintenance and all normal operation is done via the MV station in the main control room. To provide reliable and fast communication, the LEP MV unit is connected using a fiber optical link to the two local Master Bus networks. A third MV station, connected to two MP units, controls a liquefier, supplying the LHC short magnet test facility. This network as well as the one dedicated to the North Area experiment cryogenics uses analog lines and where the distances between two Master Bus nodes are greater then 30 m, standard modem links (RS232C) are used.

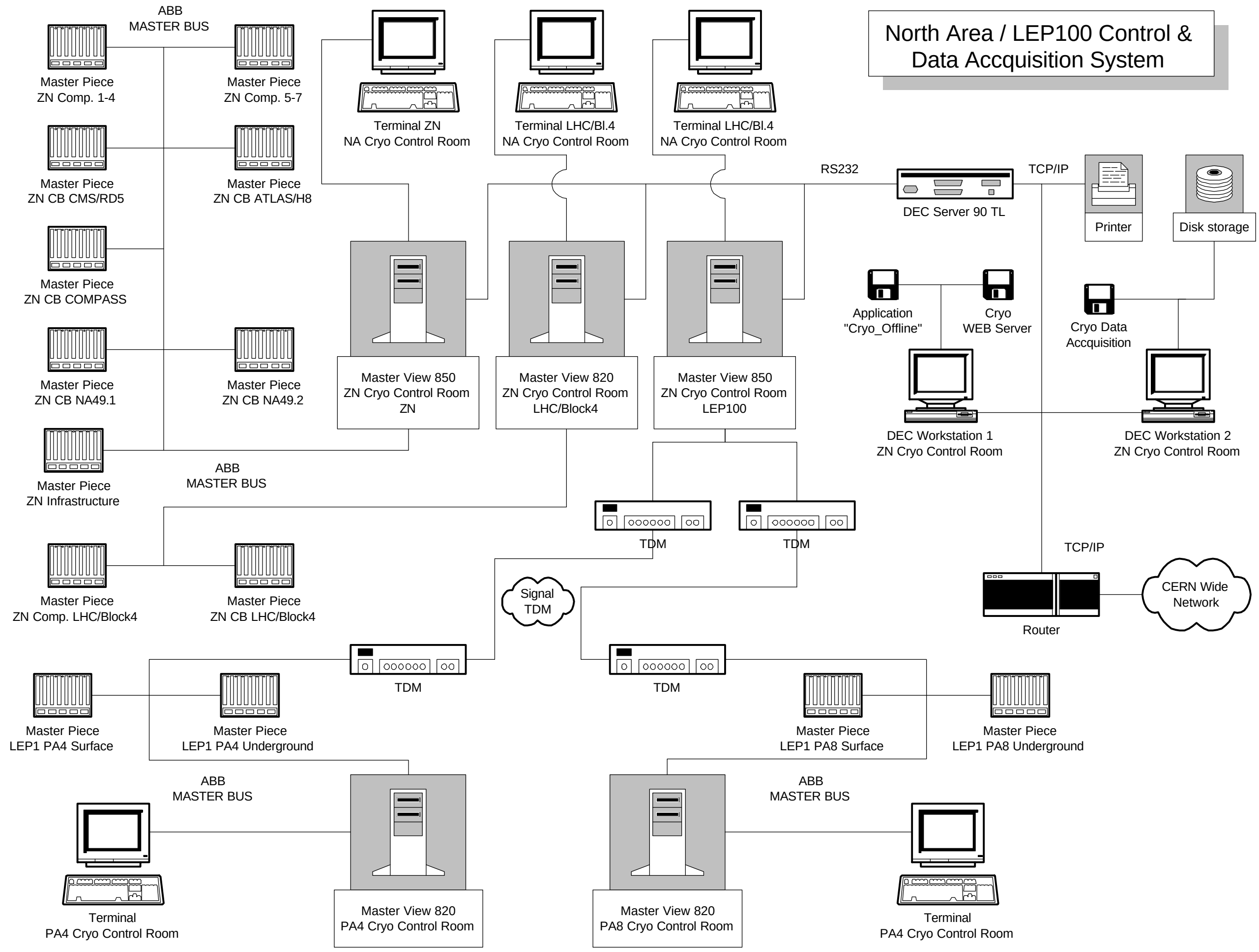

Figure 1: Structure of the North Area and LEP control and data acquisition system

2.2 The long-term historical data acquisition system

The control and supervisory system, as described above, covers well all short term monitoring of the cryogenic installation needed to control it. In addition a second system was developed, which reads out all the various process signals and alarm/event lists of the ABB MP units. The data is time tagged and stored with a repetition rate of 8-15 minutes in one central database. This allows to keep a trace of all analog and digital process information from the plants and allows performance monitoring over periods of up to one year.

Figure 1 shows in detail, how the long term data acquisition system is connected to the North Area and LEP ABB control system. Each ABB MP unit stores all analog and digital signal values from the sub-processes, controlled by it, in a local process database. The database of each MP is read out from a self programmed data acquisition software running on a DEC workstation. The data is transferred from the ABB MP units to the DEC workstation via a special ABB hardware port called ASEA Master EXCOM[5]. The EXCOM module is installed in the MV station and allows the external computer to read out indirectly all process databases of the MP units connected to its ABB Master Bus 200. To avoid additional cabling between the MV stations in the different control rooms and the DEC workstation, a Ethernet communications server[6] is installed in each local zone. This device provides a routing between the asynchronous serial link port and a thin wire Ethernet, thus allowing the transfer of the various MP process data files using the CERN Local Area network (LAN). Figure 2 illustrates how all the different control rooms are connected via the CERN LAN to the DEC workstation located in the North Area & LEP control room. The central database, which is continuously updated by the data acquisition program is kept on a network accessible hard disk (13 Gbytes), providing sufficient space to keep data accumulated by all plants during one year of operation.

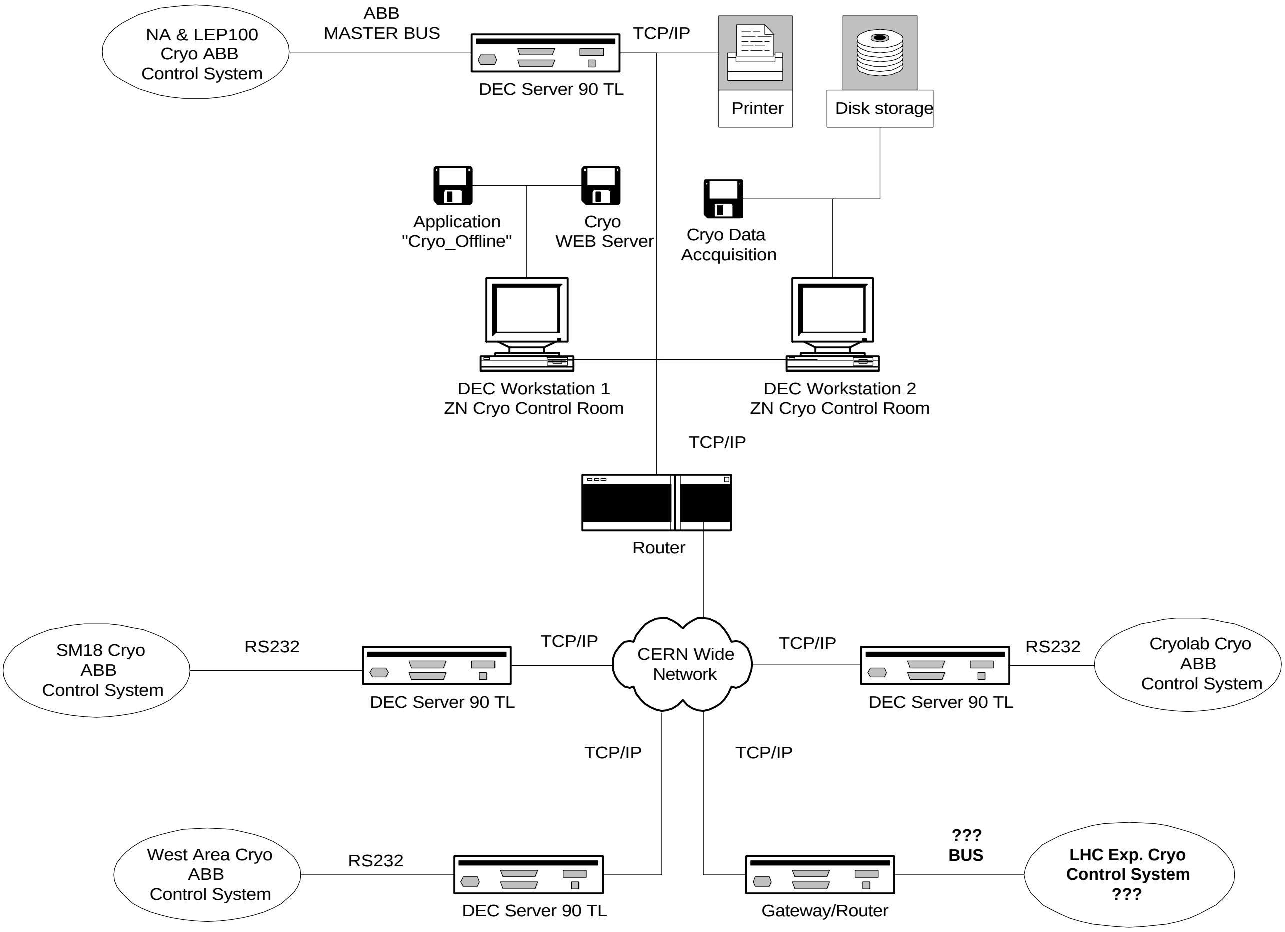

Figure 2: Detailed structure of the long term historical data acquisition system

3. INTERFACES TO THE LONG TERM HISTORICAL DATA ACCQUISITION SYSTEM

The enormous amount of process information stored in the central database, demanded also for a user-friendly operator access to the data for analyzing it off-line. Two interfaces have been established to display and analyze the process data.

3.1 The WEB interface

The WEB server has been set-up on a second DEC workstation. The software package extracts continuously process data from the central database and presents it in form of hypertext documents (HTML). Figure 3 shows the homepage of the cryogenics for experiments and test facilities WEB server (http://afcryo02.cern.ch), which is presenting an overview with the main status information for all cryoplants in operation. All animated WEB pages are updated automatically every 15 minutes with the latest process information of the central process database. By clicking on the text hyperlinks, the user has access to all analog and digital process signals as well as alarm and event lists of the installation for any period in the past 12 month. Every signal can be exported into a standard ASCII text file, which permits to produce reference curves for all important plant parameters and allows the long-term monitoring of the plant performance.

The WEB interface is used to provide the different users of the cryogenics with the latest status information, since any computer equipped with a Internet access and a WEB browser has access to it. In case of plant failures outside normal working hours, the responsible operation engineer can also perform a first diagnosis from home. This allows him to judge, if it is necessary to come in and support the on-call operator, who is alarmed automatically via his mobile telephone using an independent working Alarm Notification System (ANS).

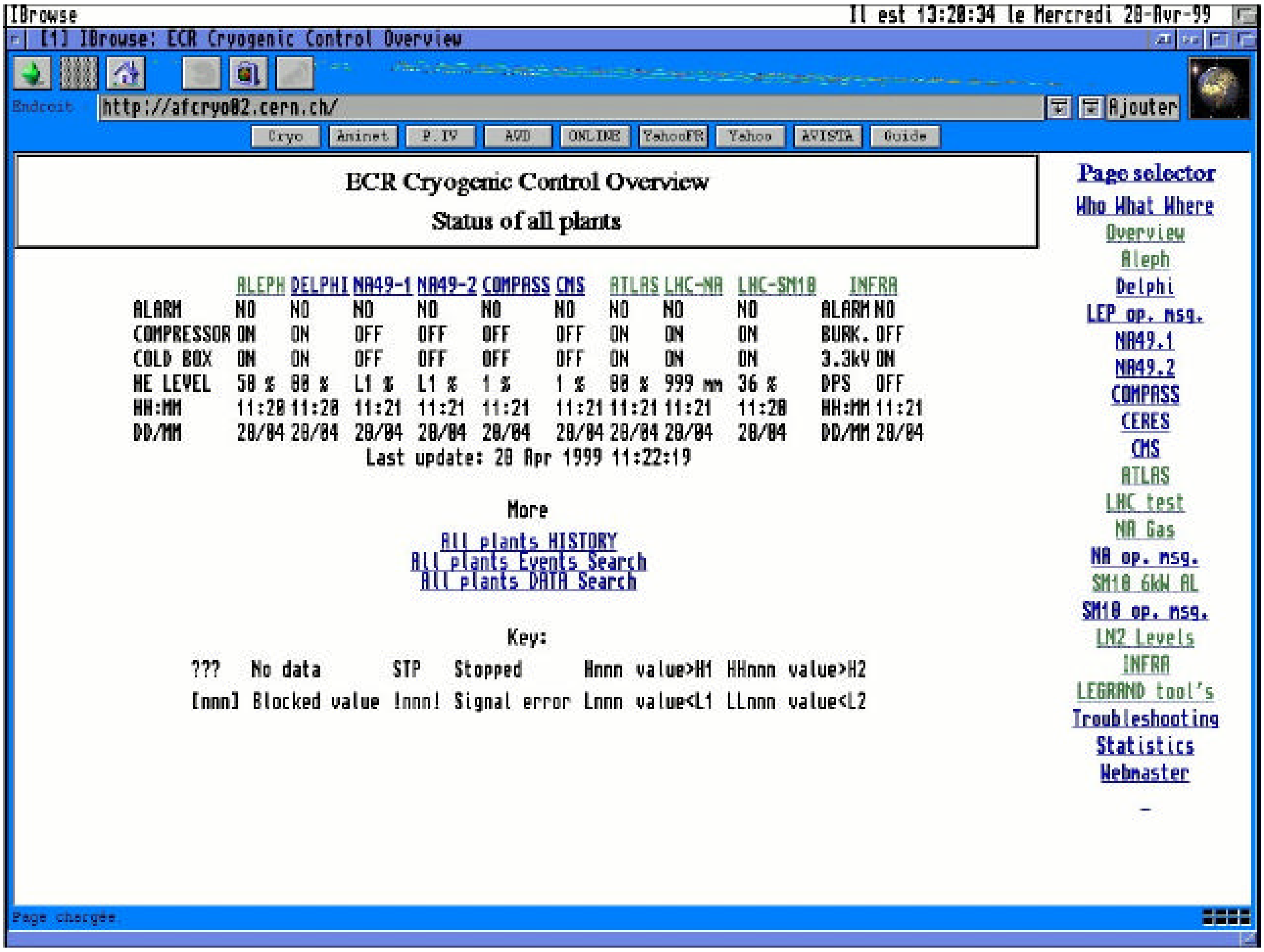

Figure 3: Homepage of the cryogenics operation section for experiments and test facilities

A special WEB page has been set up, containing level, pressure and safety information of all liquid nitrogen storage tanks (19 in total with capacities between 6000 - 50000 l) at the various CERN sites. With it, a single person can manage and plan the liquid nitrogen distribution using a special contract set-up with the suppliers.

3.2 The "CRYO-OFFLINE" interface

In case of any cryoplant malfunction a detailed off-line analysis is performed to find the origin of the problem and to avoid it in the future. For an exact problem debugging, the time evolution of several plant parameter has to be displayed in parallel. Using the WEB interface, this can be only done by exporting all the necessary data and displaying them in multi-graphs, using a standard graphical software package (for example MS-EXCEL). The disadvantage of this method is the limited number of curves, which can be displayed in one graph without loosing the overview. Therefore a second access interface to the central process database was developed, called "CRYO-OFFLINE" [7]. The software was programmed using a high level programming language (GNU C) and a graphical modeling system (SL/GMS) available for the DEC platform.

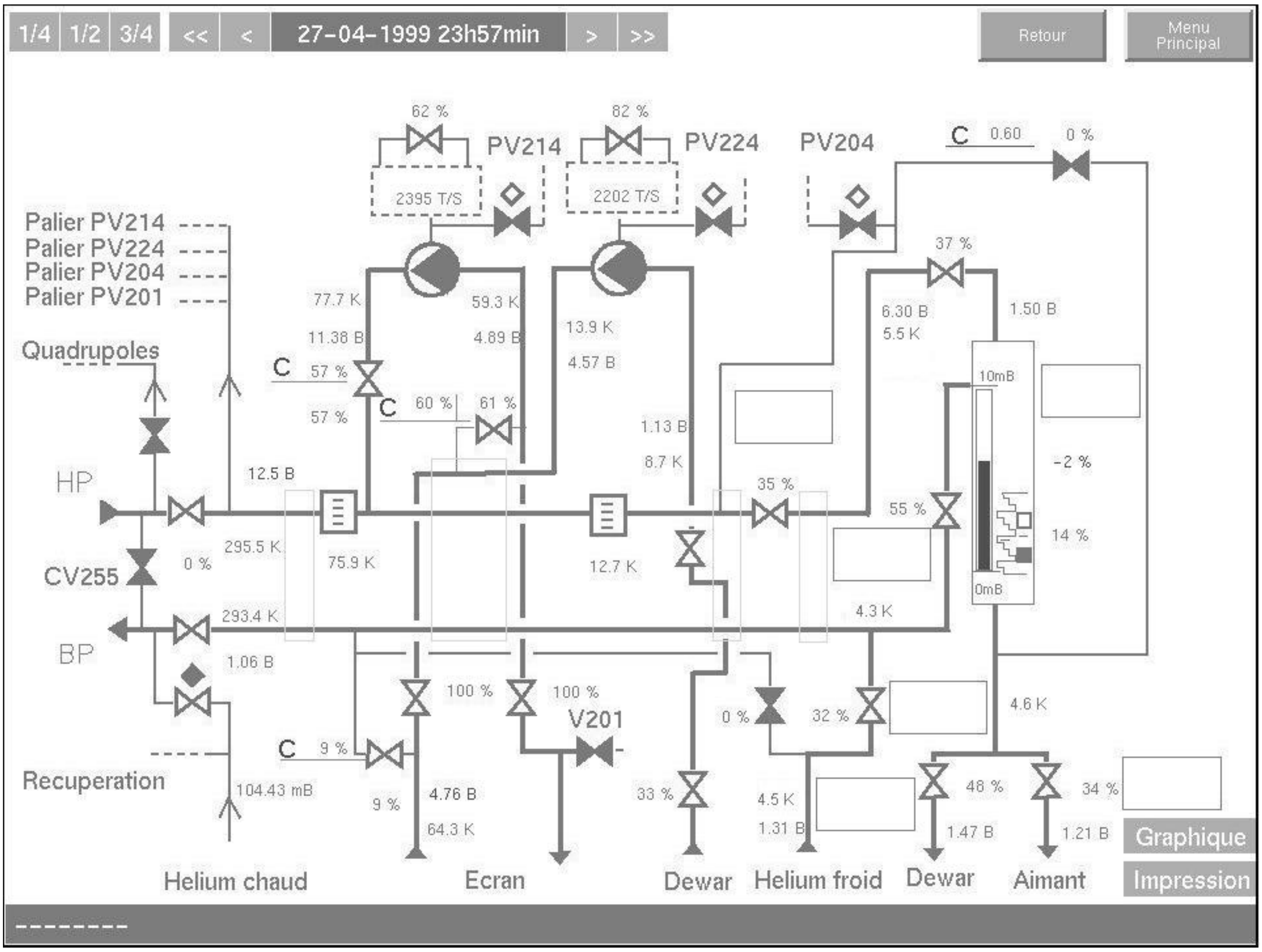

Figure 4: Animated graphical representation of the LEP PA8 cold box in "cryo-offline"

The tool allows to display time evolution of the signals with the same animated graphical representation, used in the ABB control system. Figure 4 shows a hardcopy of such an animated process diagram. Instead of displaying on-line signals, data from the long-term data acquisition system for a user-defined time period is used and can be browsed forwards or backwards in time. For all signals displayed in the mimic, also a curve over the pre-defined time period can be displayed. This form of displaying the information has the advantage that all relevant parameters can be shown on one screen, while at the same time the overview over their relation to the process is kept.

4. CONCLUSIONS AND OUTLOOK

The industrial standard ABB control and supervisory systems, presently used at CERN for cryogenics, covers very well the needs for short-term monitoring of process information. It has been complemented by a self-made data acquisition system monitoring long time periods of up to 1 year, due to the demand of the specific applications of cryogenics at CERN. Nevertheless such a long-term data monitoring could be also interesting in other fields of process control.

The system has been tested and is now under full operation for more then 2 years. Especially together with the two user-interfaces, it has been shown, that it is a powerful tool for problem debugging and plant performance analysis. The system is presently extended to include all the new cryogenic installations, which have been installed to supply various test facilities for the LHC.

5. REFERENCES

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