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Cryogenic control system of the large COMPASS polarized target

F. Gautheron[a,*,1], J. Ball[b], G. Baum[a], P. Berglund[c,d], N. Doshita[e], St. Goertz[f], K. Gustafsson[d], N. Horikawa[g], Y. Kisselev[a,f], J. Koivuniemi[c,d], K. Kondo[e], W. Meyer[f], G. Reicherz[f]

[a] *Physics Department, University of Bielefeld, Bielefeld 33501, Germany*
[b] *CEA Saclay, DAPNIA, Gif-sur-Yvette 91191, France*
[c] *Low Temperature Laboratory, Helsinki University of Technology, HUT 02015, Finland*
[d] *Helsinki Institute of Physics, University of Helsinki, Helsinki 00014, Finland*
[e] *Department of Physics, School of Science, Nagoya University, Nagoya 464-8602, Japan*
[f] *Physics Department, University of Bochum, Bochum 44780, Germany*
[g] *College of Engineering Chubu University, Kasugai 487-8501, Japan*

Abstract

The dilution refrigerator used to cool the large COMPASS polarized target is monitored through a PC running LabVIEW™ 6.1 under Windows 2000™. About 60 parameters of the target (temperatures, pressures, flow rates) are continuously plotted and checked. They are periodically recorded in an Oracle™ database and in a data file. An alarm for every parameter can be individually activated and optionally connected to a GSM (Global System for Mobile Communication) delivery message system. A web server receives and publishes the online status of the target with online tables and graphics on a dedicated COMPASS polarized target information web site. A Siemens programmable logic controller (PLC) powered by an uninterruptable source keeps the cryogenic system safe and stable during the long beam periods by controlling valves and interlocks. This safety feature protects the dilution refrigerator against potential damages in case of power failure.

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1. Introduction

The COMPASS double cell deuteron target needs the combination of a $^3He/^4He$ dilution refrigerator to maintain the temperature of the target around 100 mK and a 2.5 T superconductive magnet to keep the opposite polarizations produced in the two cells by microwaves. The goal is to extract the spin asymmetry in polarized deep inelastic muons scattering giving access to the spin structure of the nucleon [1].

To have an overview on about 60 parameters of the cryogenic system during the beam period (between 4 and 6 months), a centralized slow

*Corresponding author.
E-mail address: fabrice.gautheron@cern.ch (F. Gautheron).
[1] Present address: CERN, 1211 Geneva 23, Switzerland.

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control of the dilution refrigerator has been developed for a Windows 2000 PC running LabVIEW 6.1 [2]. After experiencing power failures during the running periods in the two first years of COMPASS it has been decided in 2003 to improve the control by adding a PLC system for the dilution refrigerator. Both control and monitoring systems provide online web information on the cryogenic circuit status.

2. The labview slow control

2.1. Design of the system

The design was chosen to provide the possibility of evolution for future development requests and to provide a simple graphical user interface. This choice has driven us to develop efficient slow control software with a high modularity. The opportunity to reuse the heterogeneous measurement devices of the previous SMC [3] target was another consideration in this development. The idea was to associate a monitoring display for each remote device. Each window provides the measurement history over the last 4 h of data taking (see Fig. 1). These graphical windows do not directly appear on the screen of the slow control PC. A top manager console gives the opportunity to open or close the windows on request. The data acquisition is a regular updating process for all probes even when the corresponding window is closed. The console provides useful information:

- the name of the datafile in production,
- the elapsed time since the beginning of the datafile production,
- a progressive bar shows the data filling.

In addition, the console gives the communication status with the database and all the remote devices connected with the slow control PC. The connection of the alarms to the mobile phone of the target expert can be enabled or disabled from this panel.

2.2. The control system

The dilution refrigerator system is monitored through several types of sensors: flow meters,

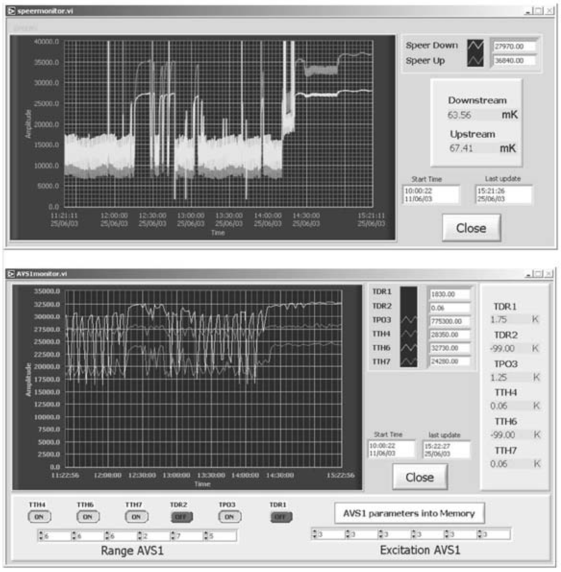

Fig. 1. Graphical display of two resistance bridges for temperature measurements. The top window gives the monitoring of the temperature measured in the upstream and in the downstream cell. The bottom window shows the temperatures measured around the target cells, near the heat exchanger and the evaporator. The fluctuations of the signals comes from the beam bunches exciting the thermometers.

pressure gauges, level meters and thermometers. All cryogenic thermometers are read by five 4-wire precise resistance bridges (AVS46 from RV Elektroniikka Oy), two of them using 6 and 7 channels multiplexer. A 32 analog channels data logger (Siemens Multireg C1732) is dedicated to the level meters, the pressure gauges and flow meters. All of these devices are read through a PCI GPIB board from National Instruments. The console manager provides a set of buttons to open a window of the dedicated device to display the parameters in graphical and numerical presentations. For the AVS self-balancing resistance bridges the numerical display is shown in Ohms and in Kelvins when the measurements are done within the calibration ranges. The measurements are updated every 2 min.

The Siemens data logger C1732 is used to plot the values on paper. An 8 h historical graph is also generated on the computer screen allowing the operator to modify the scale or to display one or more parameters. The parameters are given in a table and displayed in both raw and calibrated formats. The update is made after a complete sweep of all the 32 channels every 30 s.

2.3. The alarm system

All the parameters monitored by the LabVIEW slow control are submitted to the alarm supervision. Each of them is compared with the minimum and the maximum values set in the computer memory. By pressing the Alarm Settings button the red framed alarm settings window is displayed giving access to all the categories of alarm parameters, for example mixing chamber temperatures, pump pressures, cryogenic levels.

A green/red color code for individual slide switches helps having a clear and fast overview of the enabled/disabled alarm status of each parameter. All the settings are written in a dedicated file for an immediate recovery in case of computer problem. By default, the alarm mode is silent. In this case the operator is only informed that a problem occurs when the color of the corresponding row of the summary table turns red.

A horn and an animated alarm window are available by enabling the general alarms on the console manager. This alarm window appears on the screen and provides the parameter name and its last measurement value until the correct action is done to solve the problem. To increase the security of the dilution refrigerator it was associated an optional Short Message Service (SMS) delivery with the alarm message. The mobile phone of the target expert can be automatically reached at any time by the slow control system in case of problem. The message includes the time-stamp of the event, the name of the parameter and its value. To avoid an SMS overflow on the expert's mobile phone, the slow control is designed to renew the alarm call only every three minutes for every out of range parameter.

2.4. Online Web information

The slow control regularly records the values of the sensors into an Oracle™ database [4]. The last entries correspond to the online status of the dilution refrigerator available on the dedicated web page. All this information is world wide accessible from the CERN central web server hosting the COMPASS Polarized Target Information Center. The information update occurs every 15 min and gives the alarm status for all the parameters in dedicated tables (see Fig. 2). Each parameter is clickable to select a period of interest. There is also the possibility to look on the slow control graphical panels for every device (see Fig. 1), but the remote control through the web is disabled for security reasons. An overview of the temperatures in the different parts of the dilution refrigerator is also available on the operator display and on the web. It is updated every 2 min and displayed as a map of the system to help locating the thermometers (see Fig. 3).

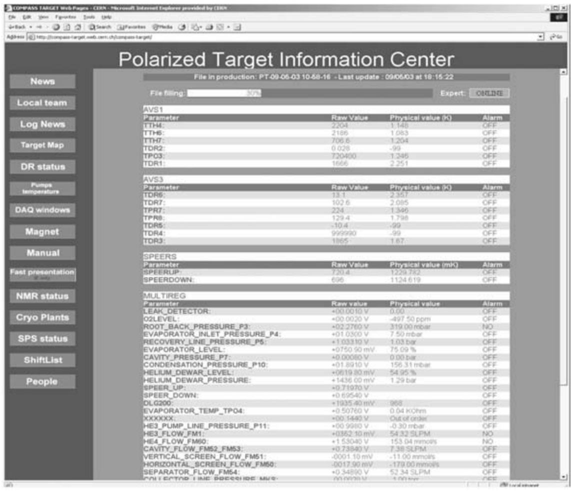

Fig. 2. View of the internet page providing the online update information for pressures, temperatures and flow rates.

3. The programmable logic controller

Originally, the LabVIEW program was expected to monitor and to control the cryogenic system of the target. After experiencing many general power failures in the experimental hall in 2001 and 2002 during which the control system became blind and could suddenly restart in a incorrect way, it was decided to add a PLC system to run simultaneously with the LabVIEW program. This

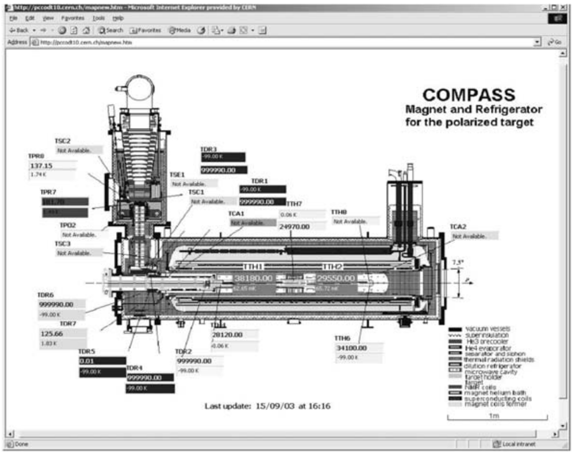

Fig. 3. A map overview of the dilution refrigerator showing the location of the thermometers and the corresponding temperatures.

solution was chosen because a PLC is easy to install, the time for the software development is usually quite short using the tools provided with the PLC. Such a system is well adapted for the remote control needed in our case.

3.1. Description of the set-up

A Siemens S7-300™ PLC system was selected to run in parallel with LabVIEW™ to insure the safety of the cryogenic system of the COMPASS target. This system which is an industrial standard powered by a 48 V UPS network is not sensitive to potential power failures. The modular set-up is made of a CPU315-2DP module connected to several distributed I/O racks spread out over 3 locations (see Fig. 4) for a total of 49 channels (see Table 1): the target platform which is not accessible during beam time, the pump room which is outside the experimental hall, and the control room where the CPU is checking all collected parameters. The centralization of the information from each place is done by using a Profibus™ network connection. The parameter values are checked every few milliseconds. The hardware is configured through a connection to a PCI card (CP5611 MPI) in a PC running the STEP 7™ software.

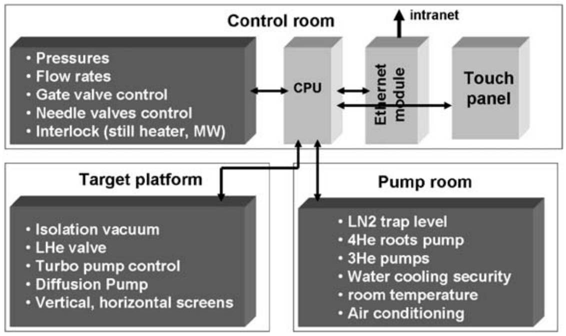

Fig. 4. The PLC organization.

Table 1
The number of each type of PLC input/output

	Analog input	Analog output	Digital input	Relay control
Control room	12	2	3	4
Platform	2	0	6	4
Pump room	4	0	10	2

The program is designed on a PC before being uploaded to the 48 kBytes CPU memory. After uploading the PC connection is not needed anymore: the PLC system runs in a stand-alone mode. The code is also recorded in a 64 kBytes flash EPROM memory card which is removable from the CPU unit. In the rather improbable case of software corruption it will be automatically reloaded into the CPU memory after a general restart of the system. A connection is only necessary for reloading the program in case of modification or update. This is for example the case in redefining the acceptable range for the parameters. They cannot be modified directly through the touch panel.

3.2. Control and internet monitoring

The PLC automatically controls the liquid nitrogen level for the ^{3}He gas purifier, the emergency turbo pump system for the isolation vacuum and the interlocks for the still heater, microwave system and ^{3}He pump system. Some of the valves can be remotely operated from a *touch panel* located in the control room. This graphical

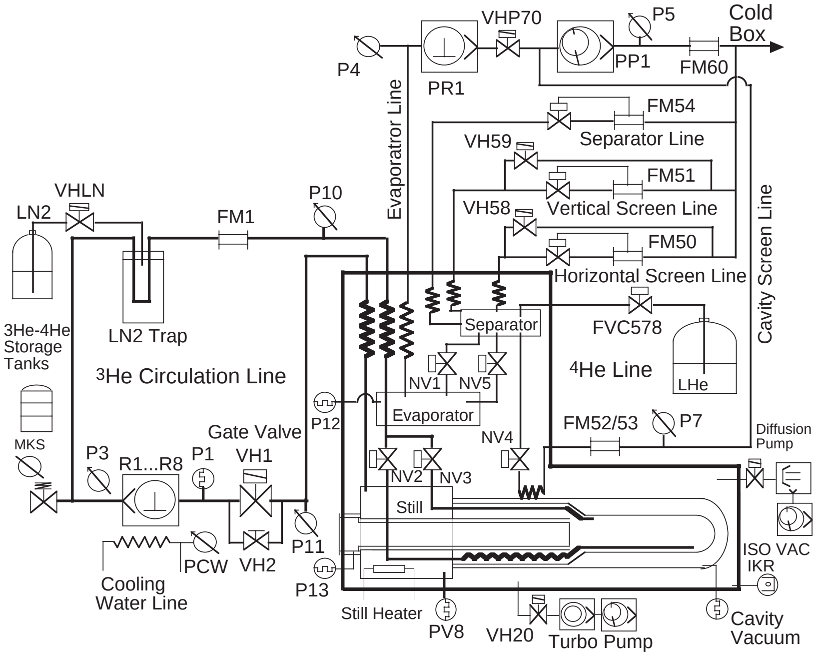

Fig. 5. The drawing of the cryogenic circuit for ^{4}He and ^{3}He.

interface also provides the status and the evolution of the parameters. It has a tree structure with two main branches accessible from the main page: the first one for the control which is reserved for the experts and the second one for monitoring mainly used during the beam periods. An ethernet module provides all information and status of the control system to the target team.

The monitoring of the cryogenic circuit (see Fig. 5) is divided into several main sections on the display of the touch panel (see Fig. 6). A colored indicator stands in front of each of them. If all values are within their ranges the indicator stays green. It turns red when at least one of the parameters goes outside its normal range. In this case the PLC starts a buzzer in the control room. The operator has to select the concerned section to know in more detail what is wrong and to take the right action or to inform the expert if an intervention is needed.

The ethernet module CP343-1 IT provides the same information as the touch panel and with the same internal organization. For more detailed information the drawing of each cryogenic circuit has been added with the corresponding values of the different gauges (see Fig. 7). The 10 Mbytes of memory allows the system to provide such a detailed presentation.

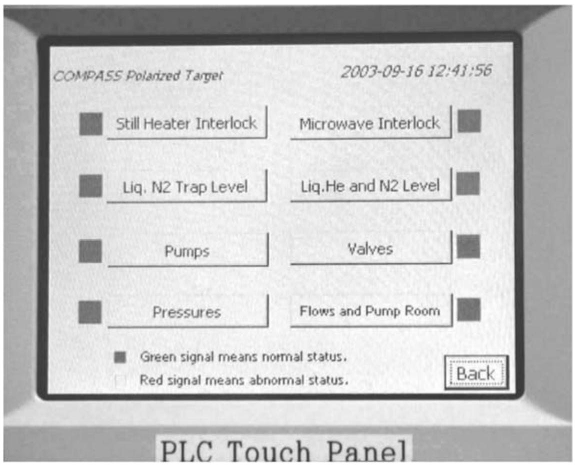

Fig. 6. A picture of the main monitoring window of the touch panel.

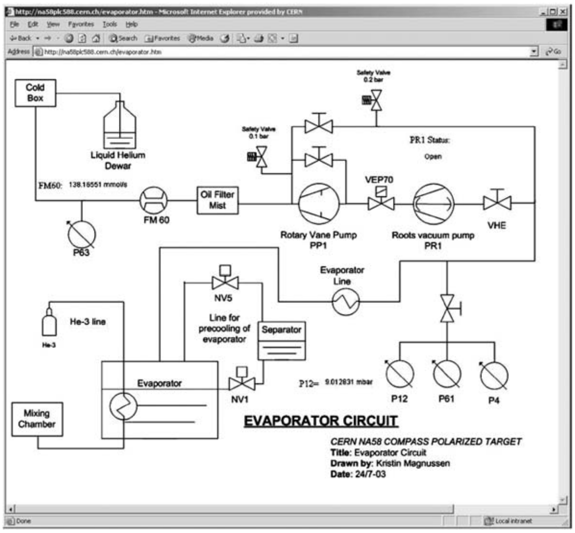

Fig. 7. An example of online information page for the evaporator circuit.

Table 2
Summary of connection availabilities for the two systems

LabVIEW		PLC
√	Thermometers	
√	Pressures gauges	√
√	Level meters	√
	Valves	√
	Interlocks	√
√	SMS	
WWW	Web info	CERN intranet

For security reasons the accessibility is limited to the CERN intranet only. This feature allows the target team to stay informed without staying permanently in the control room. For the near future it is expected to activate an SMS alarm in the target expert's mobile phone in case of severe problem.

Finally, the Table 2 shows the full complementarity of LabVIEW and the PLC working in parallel and that all connections of the dilution refrigerator are covered at least by one of the systems.

4. Conclusion

The slow control of the COMPASS polarized target has been designed using two different platforms: LabVIEW and a PLC system. The two systems complement each other. Their graphical interfaces are user friendly, that is quite helpful for the occasional user of the cryogenic system. After several months of nonstop run, it has been proven that our slow control is safe, stable and reliable for this distributed cryogenic circuit. All software and hardware components are modular and easily extendable. Quite particular care was taken to provide online monitoring access through the web.

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