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COMMISSIONING THE CONTROL SYSTEM FOR CRYOMODULE CRYOGENICS DISTRIBUTION SYSTEM IN TEST STAND 2

E. Asensi*, W. Hees, N. Elias, M. Boros, P. Van Velze, J. Fydrych
European Spallation Source ERIC, Lund, Sweden
W. Gaj, IFJ PAN, PL-31342 Krakow, Poland

Abstract

The linear accelerator for the European Spallation Source (ESS) contains 13 cryomodules with 26 double spoke cavities and 30 cryomodules with 120 elliptical cavities [1]. Before installation, these cryomodules will be tested in two dedicated test facilities: Test Stand 2 (TS2) at the ESS site in Lund and the FREIA Laboratory at Uppsala University for the elliptical and spoke cryomodules respectively [2].

In this paper, the authors present the commissioning of the Programmable Logic Controller (PLC) based control system for the cryomodule cryogenic distribution system (CDS) in TS2. Once the cryomodule is connected to the CDS, these circuits will allow the circulation of gas Helium at 4.5 K and liquid Helium at 2 K to cool down the niobium cavities and reach the material superconducting state, as well as to keep a thermal shield with gas Helium at 50 K. Cryogenic valves, temperature and pressure sensors are controlled and monitored to operate this system successfully from a Control Room using dedicated Operator Interfaces (OPI) developed in CS-Studio and following the Experimental Physics and Industrial Control System (EPICS) architecture.

INTRODUCTION

The CDS for TS2 is dedicated to transferring cooling power from the Test and Instruments Cryogenic Plant (TICP) to the ESS elliptical cryomodules under their site acceptance tests in the test stand bunker. The system includes a cryogenic transfer line (CTL), one valve box and four auxiliary process lines (Fig. 1).

The CTL runs from the TICP cold box in the cold box building to the test stand bunker placed in the klystron gallery. The line is a vacuum insulated multichannel line and its vacuum jacket houses four cold process lines (so-called headers), thermal shield, supports and thermal compensation system. The cryoline ends in the test stand valve box, in which four branch process lines connect the headers with the cryomodule cold circuits. Thus the whole system consists of four main and four branch cold process lines [3].

All the CTL cold main process lines at the interface to the cold box are equipped with temperature sensors. These sensors are mainly dedicated for the measurements of the thermal performance of the whole CDS. Other instrumentation required for the commissioning tests, such as flow and pressure transmitters, are located in the cold box and are contracted out separately. The valve box is dedicated for the direct connecting of the tested cryomodules and controlling

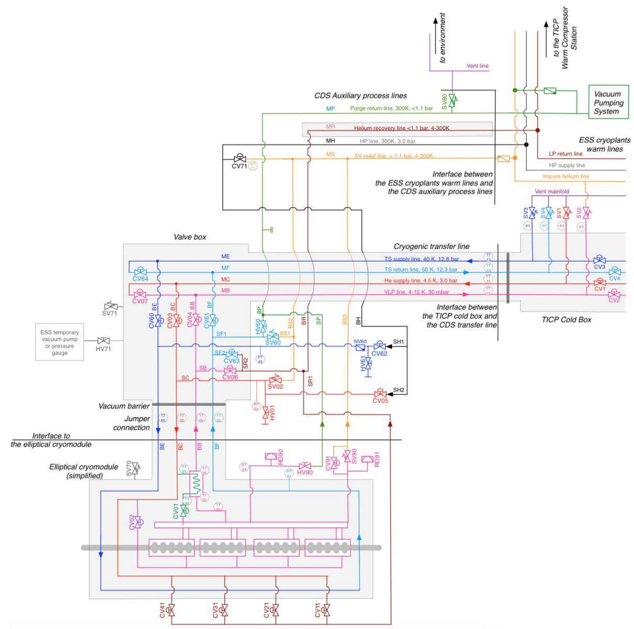

Figure 1: CDS Process and Instrumentation diagram.

the helium flows in different operation modes. For these purposes it is equipped with a branch cryoline (so-called jumper connection) and a set of control valves. The branch cold process lines are equipped with temperature sensors as well as with pressure transmitters. These sensors and transmitters are used to measure the thermodynamic states of the helium flowing in and out of the cryomodule. For this purpose they shall be supported by pressure transmitters installed on the cryomodule circuits. The mentioned temperature sensors are located in the jumper connection close to the interface to the cryomodule [3].

The Control System in TS2 is developed to control the processes in the cryogenic distribution system, valve box and cryomodule in TS2, in order to cool down, maintain and recover the elliptical cryomodule under test from cryogenic conditions, needed to allow the superconductive Radio-Frequency (SRF) to test and operate the cavities in the cryomodule.

CONTROL SYSTEM ARCHITECTURE

The architecture of the control system for TS2 includes sensors and actuators for cryogenics, cooling water, vacuum, motion control and RF (Fig. 2). These last two disciplines are not PLC controlled and therefore out of this scope, all the previous disciplines are connected to signal conditioner elements or power supplies to be controlled by a PLC controller. OPI, archiver and alarm services are developed and

* emilio.asensi@esss.se

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connected to the PLC through the ESS EPICS Environment (EEE) [4].

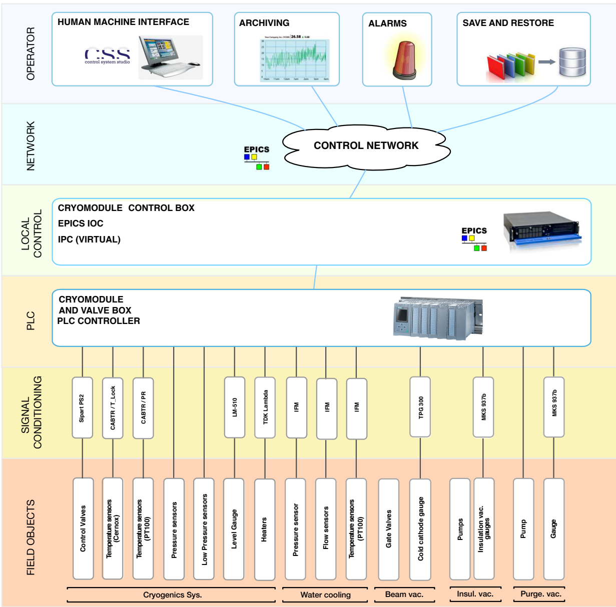

Figure 2: Cryogenic Control System Architecture.

TS2-CDS Controls consists of:

- 11 positioners for cryogenic valves with need of remote electronics
- 1 PS2 drawer with remote electronics for 15 cryogenic valves positioners
- 7 cernox temperature sensors consisting on 2 nominal plus 1 redundant sensor in the TS2 side close to the jumper connection and 2 nominal plus 2 redundant sensors in the TICP side, by the CTL
- 6 PT100 temperature sensors consisting on 2 nominal sensors in the TS2 side and 2 nominal plus 2 redundant sensors in the TICP side
- 8 Thermolock temperature transmitters
- 3 Honeywell pressure sensors
- 3 Sensotec pressure transmitters
- 1 ITR 90 vacuum gauge
- 1 PLC including Power Supply, CPU and Input/Output cards
- 1 Coupler for profibus DP/PA bridge
- 1 Input/Output Controller (IOC) in virtual Industrial PC
- 1 OPI panel

COMMISSIONING

PLC Controls

As any other automated PLC-based control system developed at ESS, the control system for the cryomodule cryogenic has been generated through PLC Factory [5] retrieving the information of the field devices from the Controls Configuration Database (CCDB) [6]. This method creates the base code to control field devices by passing the EPICS pvs associated to each object type to both the PLC and IOC allowing the communication of data through EPICS to visualize and manipulate the system using devices from the Cryogenics library inside OPIs developed in CS-Studio Display builder [7].

Analogue Measurements

Temperature sensors are connected with 4-wire configuration to Thermolock conditioners which convert resistance to 4–20 mA and give selection range bits to show the temperature range area where the sensor is reading, as cernox resistance scale is converted to 4 sub-scales in the output signal. However, some resistance could not be read during the first cool down even directly from the flange, which prove broken wires in the inner connections. Some other sensors showed outputs corresponding to a different calibration or different location, assumed swapped (Fig. 3). It was also found that all cernox showed unreliable measurements and fluctuations when changing range from the transmitter, being unstable during periods up to 30 and even 60 minutes. This was originally associated to bad sensor thermalization and overheating when the excitation current from the transmitter changes. In addition, some Thermolock temperature transmitters in TS2 side were powered with inverted polarity, which may had damaged the transmitters according to the manufacturer and so were replaced with new ones to ensure good functionality. As thermolock range bits did not provide enough current for the PLC digital inputs (DI), 3 KOhm resistors had to be placed between 24 V power source and the bits output to increase their current.

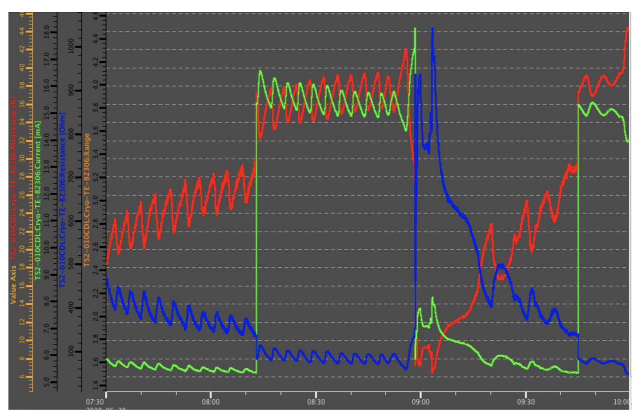

Figure 3: Temperature readings during first cool down.

After first cool down, vacuum was broken in the CDS to open the jumper connection and CTL and fix the broken wires in the sensors, to verify PT100 and cernox position in the lines, to improve the cernox thermalization. Second cool down followed the repairs and good results were seen on the TICP side, while the measurements in TS2 side were still showing inconsistencies (Fig. 4). The only difference between these two subsystems is the length of the cable between the sensor and the temperature transmitters, which is 5 m in first case and 30 m in the second, and so an investigation was carried out concerning cable type and capacitance.

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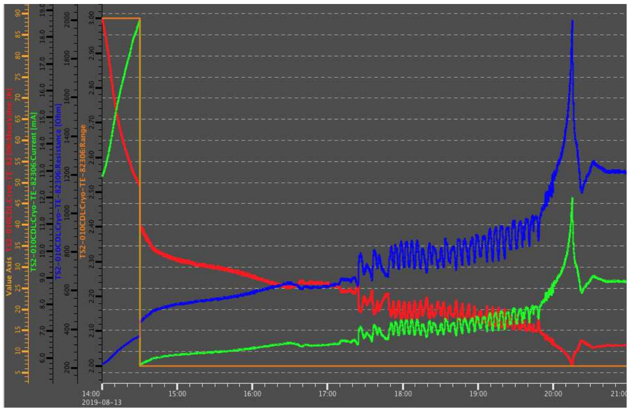

Figure 4: Temperature readings during second cool down.

Indeed, the capacitance of the cable presents a big problem when sending pulse-modulated low excitation currents at long distances, and so is recommended to use individual shielded twisted pairs cables with proper grounding to prevent noise to affect the measurements. After an improvement on the cable grounding and a zeroing on the feedback loop, the measurements were restored and expected to be reliable. However, some problems with resistances above 38 kOhm seem to still be present and the performance should be checked during the next cool down.

Actuators

Cryogenic valves use Sipart PS2 positioners with remote electronics due to radiation levels in TS2 bunker. The remote electronics are collected within a drawer located in the control rack, which allows automatic initialization of the valves if the right conditions are met and which is connected to the PLC through a profibus DP/PA coupler. All valves but one were successfully commissioned during the first cool down, however, many mechanical adjustments were needed to bring the positioners within the valves margins, sometimes obstructed by fixed metallic compressed air lines. The failure in the last valve initialization was identified as a misconnection in a 50-pins connector and a spare channel was used to rapidly fix the problem.

CONCLUSION

The commissioning of the CDS for TS2 took more than a month, repairs and two cool downs, while ideally it was expected to be done in a week. As a first time installation, more tests, FAT and SAT of the hardware and software components would have found some of the problems encountered during the commissioning. Lack of time and resources is always a complication when working with a new system and delays due to unexpected events must be considered in future iterations. Recommendations for improvement after the commissioning are the following: compressed air lines need to be more flexible or installed after positioners adjustments and calibrations, possibly done with flexible hoses, have redundancy for every important sensor, verify calibration parameters in advance, and check every sensor's resistance before and after closing the mechanical interfaces.

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