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

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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.

CRYOGENIC DISTRIBUTION SYSTEM IN TEST STAND 2

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. All the CTL cold main process lines at the interface to the cold box are equipped with temperature sensors 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 [3].

CONTROL SYSTEM ARCHITECTURE

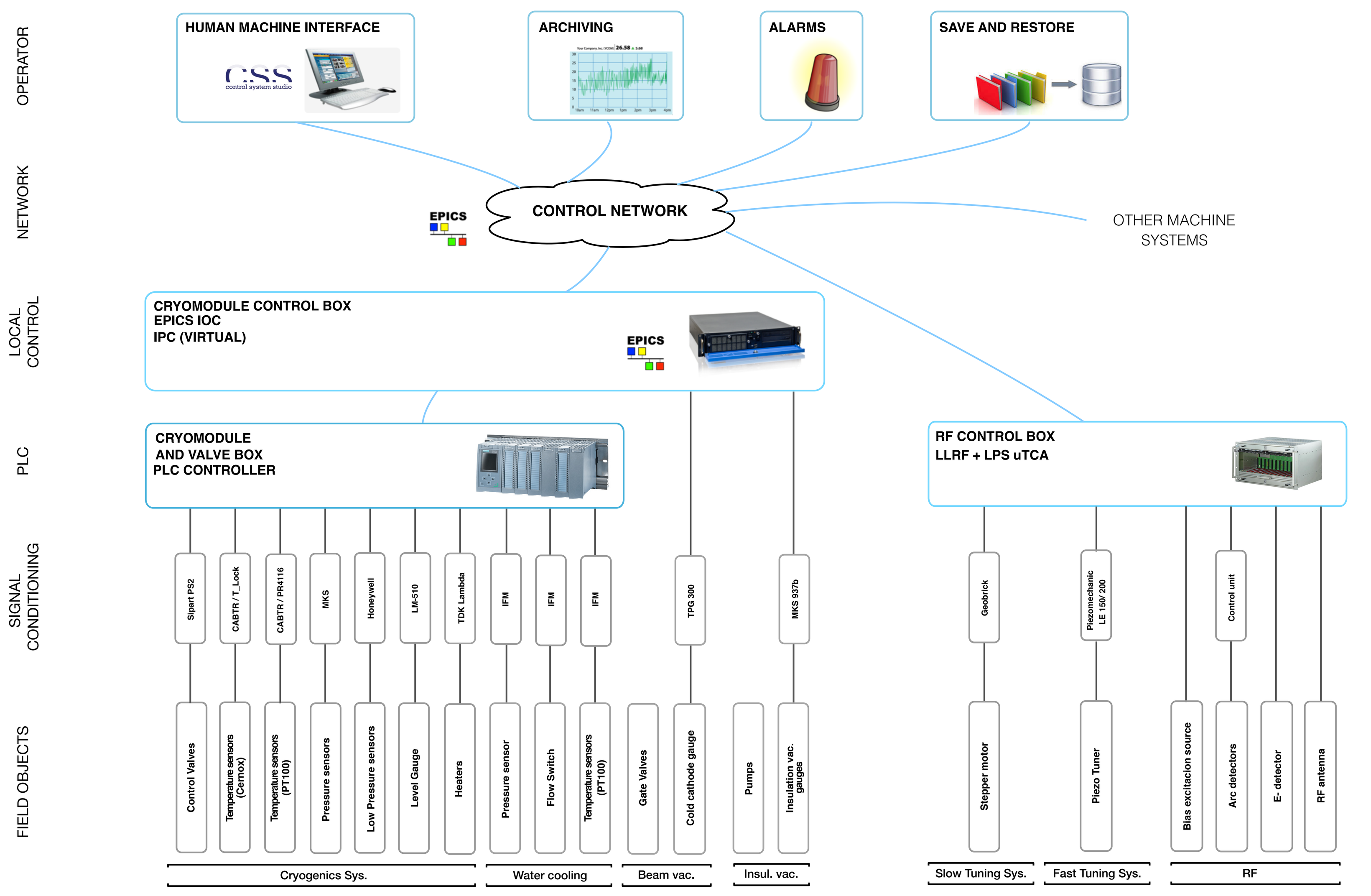

Figure 1: TS2 Control System Architecture

The Control System in TS2 is developed to control the processes in the CDS to cool down, maintain and recover the elliptical cryomodule from cryogenic conditions, needed to allow superconductive Radio-Frequency (SRF) to test and operate the cavities in the cryomodule. The architecture of the control system includes sensors and actuators for cryogenics, cooling water, vacuum, motion control and RF. 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 connected to the PLC through the ESS EPICS Environment (EEE) [4].

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].

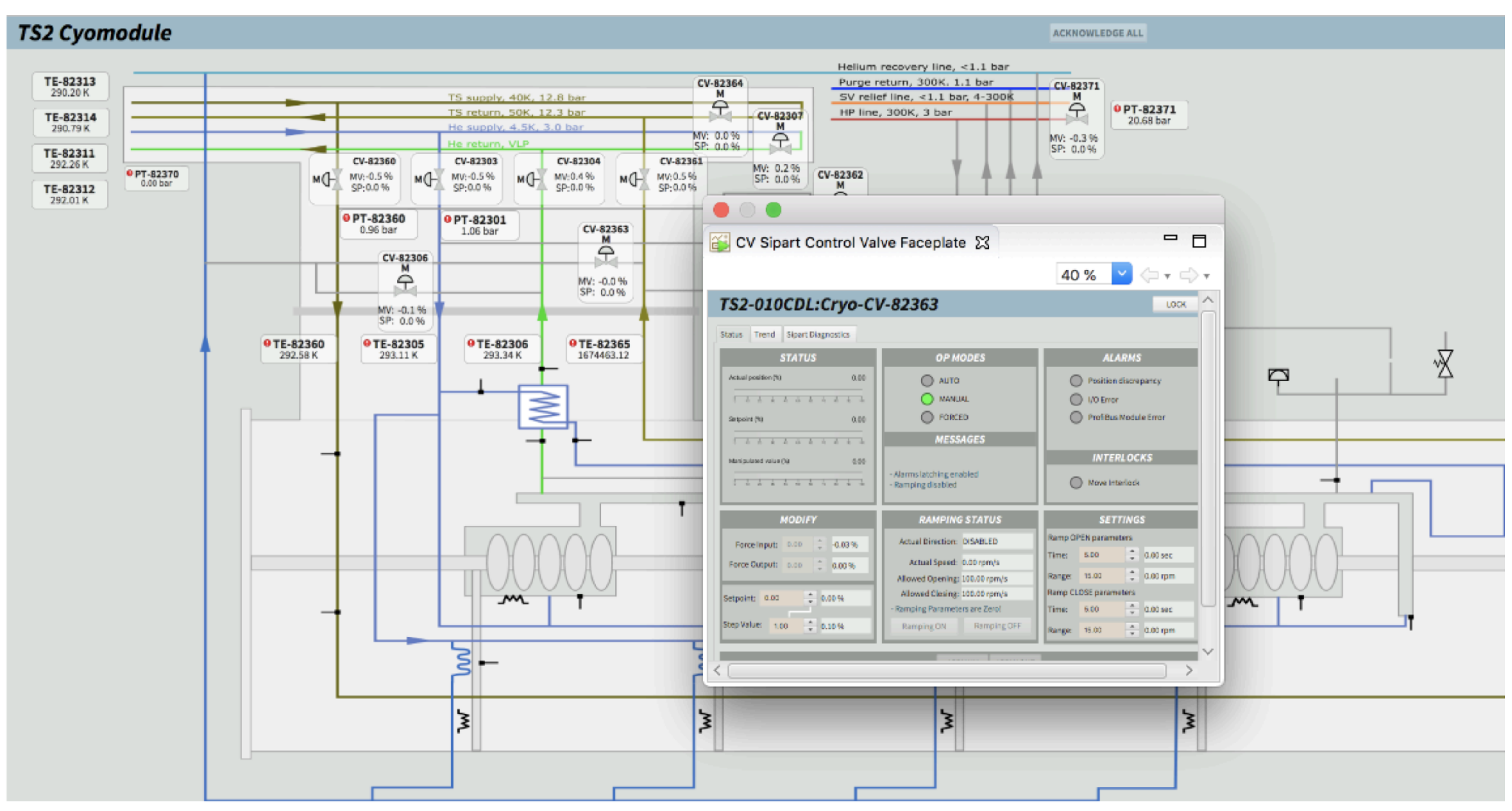

Figure 2: OPI designed for the CDS commissioning

COMMISSIONING

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 and 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 as 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.

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 were assumed swapped. 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, thermolock range bits did not provide enough current for the PLC digital inputs and 3 kΩ resistors had to be placed between 24 V power source and the bits output to increase their current. After first cool down, repairs were done to fix the found problems. 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. 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.

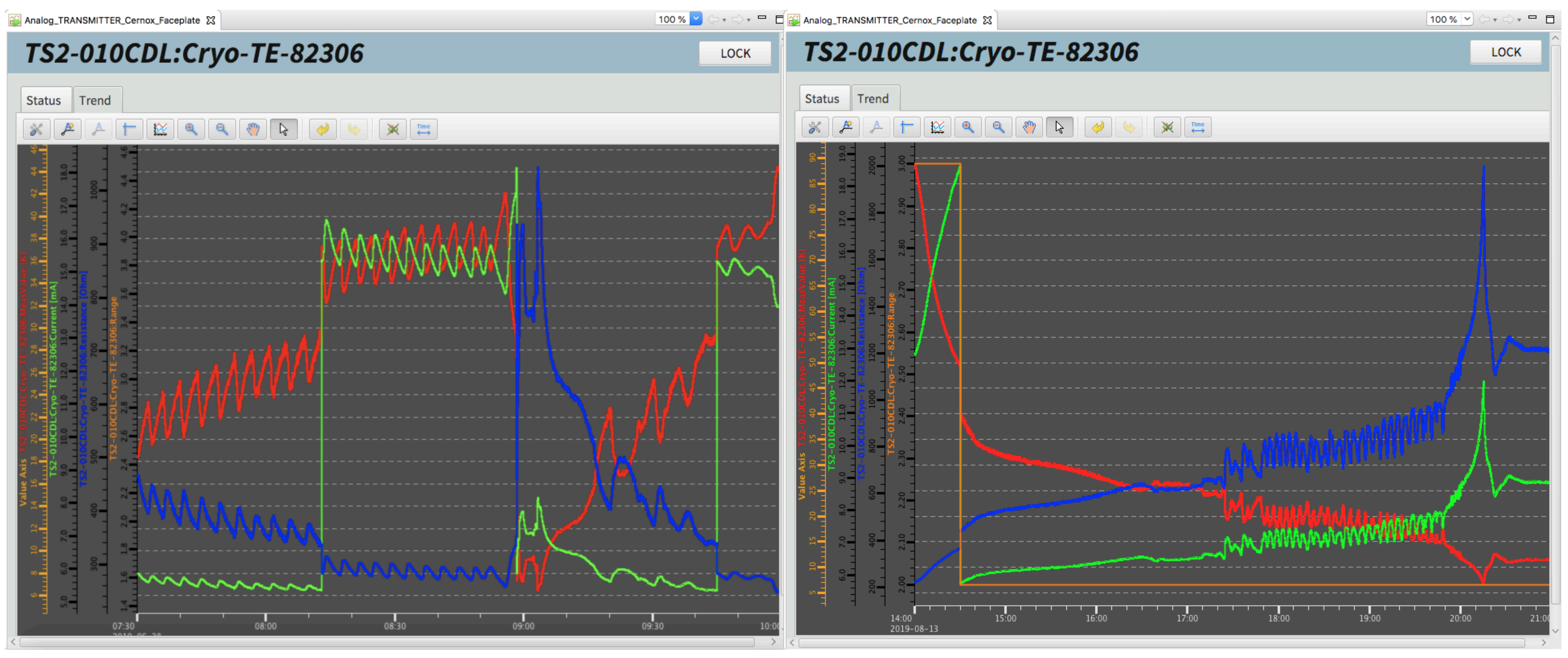

Figure 3: Measurements during first and second cool down, respectively

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 have appeared in tests with resistances above 38 kΩ and the real performance should be checked during the next cool down.

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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