(C1Po1F-03) Design, Development and Commissioning of the Control System for the cryogenic distribution system at ESS

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INTRODUCTION

The cryogenic distribution system (CDS) at the European Spallation Source (ESS) connects the refrigeration plant with the linear accelerator, consisting in 13 spoke and 30 elliptical cryomodules that are cooled at 2K via multi-transfer lines, individual valveboxes for every cryomodule and an endbox. The designed control system monitors and controls the cooling helium flow through the CDS. The controls architecture for the CDS is based on one Programmable Logic Controller (PLC) per valvebox and another one for the endbox, which are integrated into EPICS through the Controls Network and takes care of the process functions, making it a total of 44 PLCs. This type of integration allows for the remote operation of the CDS from the control room and the necessary interaction of the control system with other related systems and EPICS services like archiving, alarms and save-and-restore. Pre-commissioning activities like loop checks, temperature curve validation, pressure sensor calibration and valve initialization started in summer 2022. Eventually, the system was ready for commissioning and a first cooldown was performed in December 2022. The paper describes the design, development and commissioning of the control system and diverse challenges during the deployment and commissioning activities. Future activities are discussed including the implementation of a sequencer for automatic cooldown and warmup, integration with the cryomodule controls and a master PLC to handle the helium management.

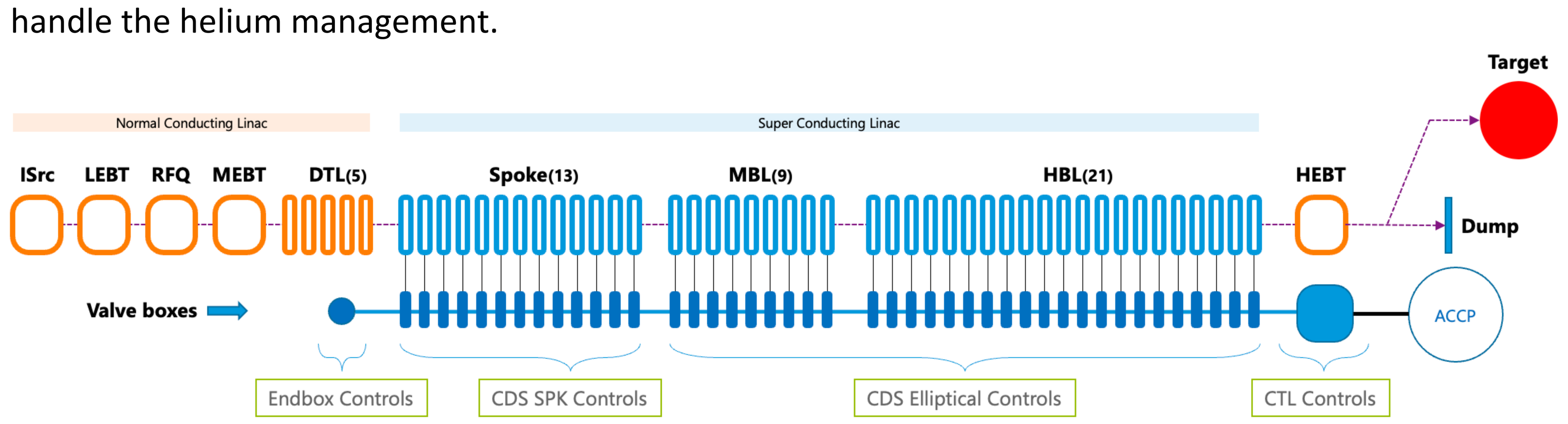

Figure 1: CDS Controls representation in the LINAC layout

CRYOGENIC CONTROLS DESIGN

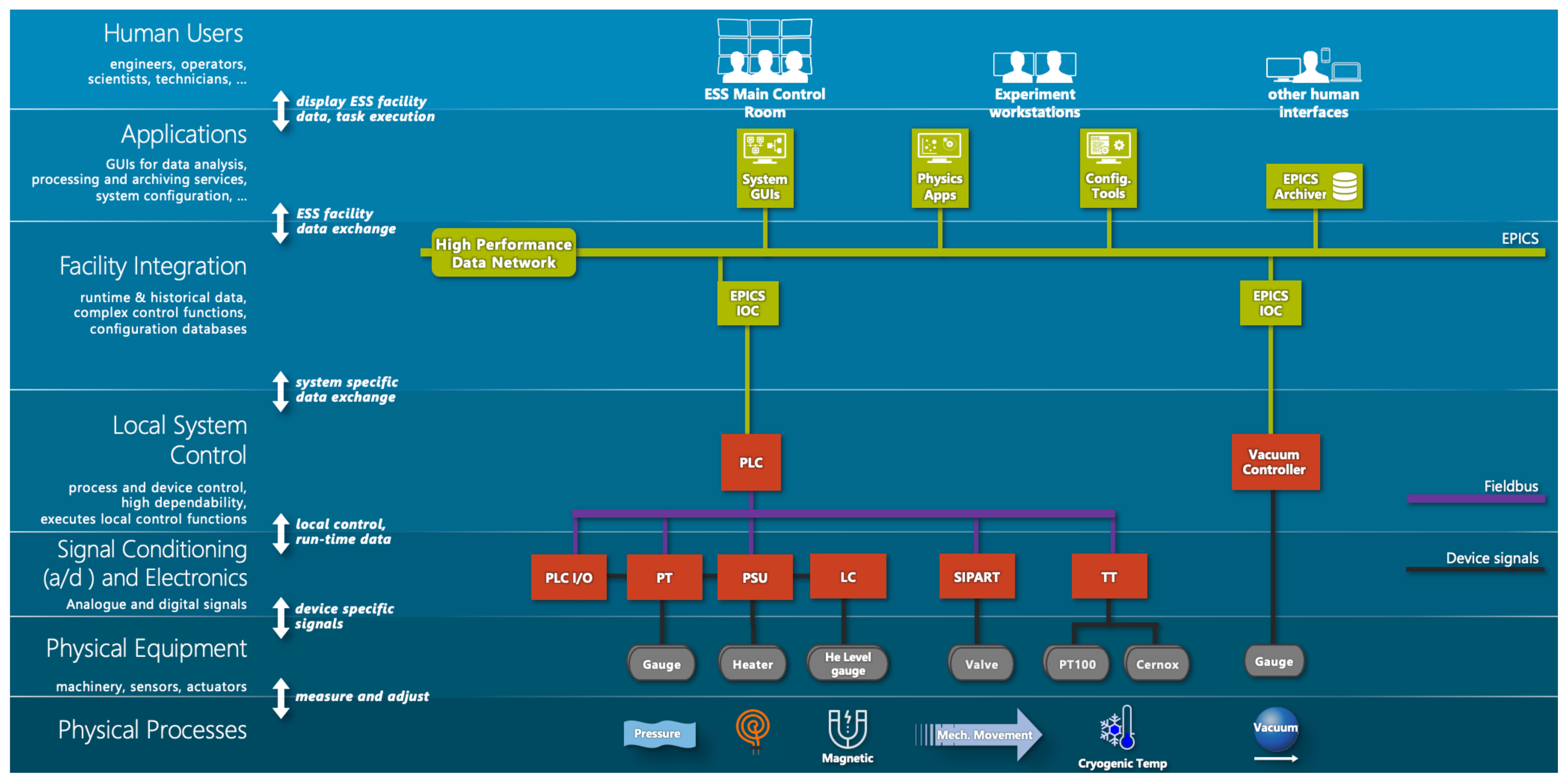

Figure 2: CDS Control System Architecture

ESS control system infrastructure has a series of tools to streamline the generation of PLC code using the EPICS environment and scripts written in python 2.7. The most relevant of these tools is the PLCFactory, that fetches the field devices information from pre-filled databases: the Naming Service, the Controls Configuration Database (CCDB) and device type templates stored in gitlab, to generate EPICS records, TIA Portal datablocks, and the EPICS layer for the PLC and IOC to communicate.
The development in the PLC then continues with the use and characterisation of handler function blocks containing the signal treatment and calibration, and association of the values to the generated datablocks for EPICS communication, including alarms and any needed safety function.

The OPIs are developed considering the stakeholder perspective as they are the final users of the system and therefore have to be intuitive, purpose-made and visually clear.

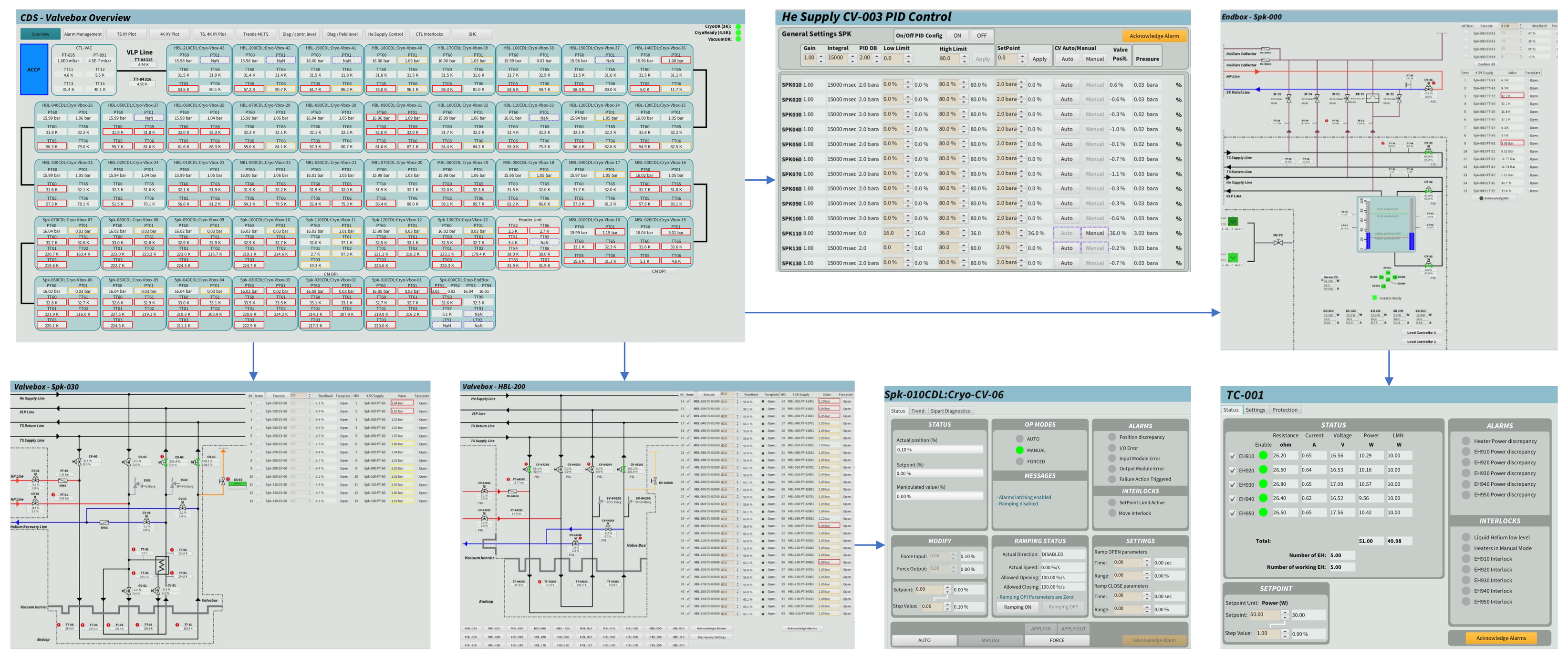

Figure 3: CDS OPI structure

COMMISSIONING ISSUES

Many issues were found during the initial days of the CDS cooldown leading to a stressful situation and friction within the different team members:

1. Temperature measurement issues in CERNOX sensors:
    - Wrong Calibration curves
    - Electrical rack grounding
    - Cable short circuited to ground inside cryogenic pipes
    - Sensor isolation and mounting position
    - Others?
2. Variable Power to heaters issues in Prototype power supply:
    - Support from manufacturer
    - Configuration without documentation
    - Not buying off-the-shelves products
3. System stability issues:
    - Leaving test code in PLC
    - Forgetting about it

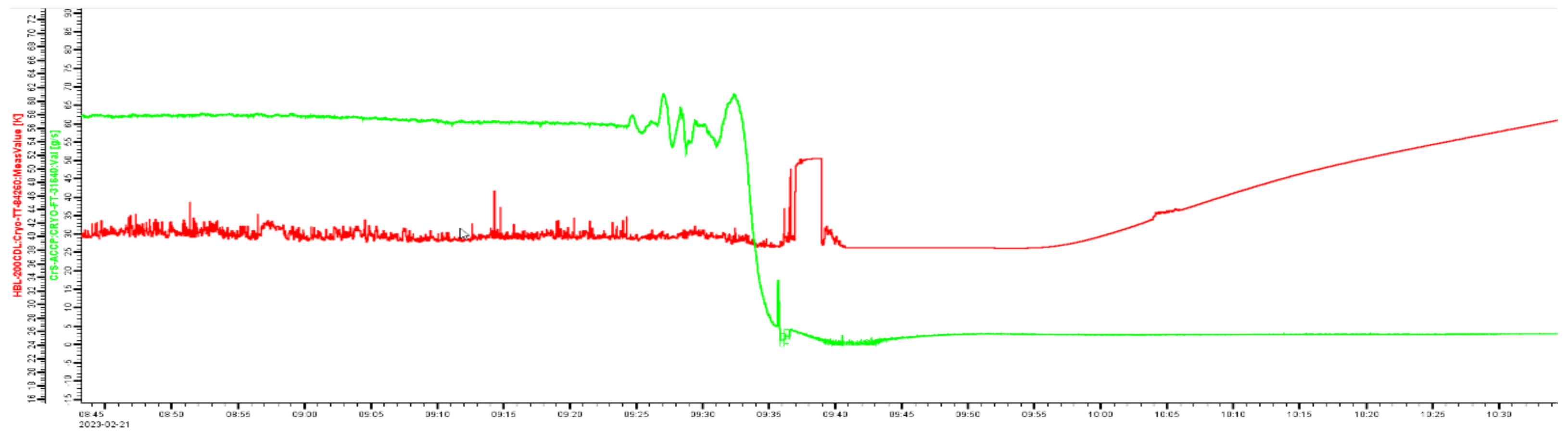

Figure 4: Direct correlation between temperature noise and flow

CONCLUSIONS AND FUTURE WORK

Better planning and organisation were applied after the first cooldown in preparation to the second cooldown leading to higher quality controls and more satisfied users. It is therefore proven that a system can be well designed according to specifications and fulfilling the requirements but still fail in the execution if the stakeholders are not involved in the development phase, mostly if it is a new implementation not tested yet in production. The automation engineer working in cryogenic controls for particle accelerators needs to be able to work in an agile environment and adapt to the evolving circumstances, as some of the conditions cannot be known until the system is fully commissioned.

The next plan for the CDS cryogenic controls effort is to continue adding automatic functions to the system as well as the full integration of Operating Modes to operate the system using State Machines, allowing the programming of more complex control logic. Other activities are the building of a CERNOX test station, and to explore new temperature transmitters to mitigate the short-circuited sensors issue using an effective 3-wire configuration. Last but not least, is to continue the development of Cryomodule controls in parallel and integrate them with the CDS controls.

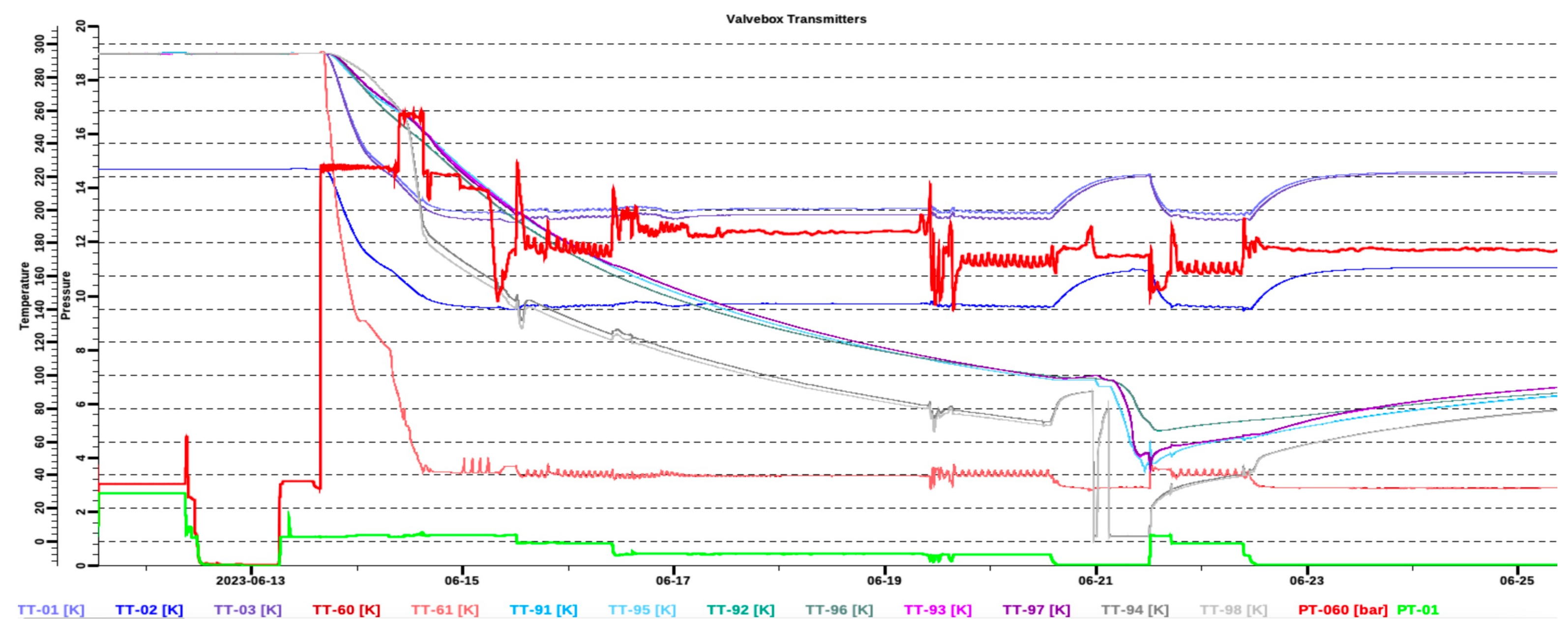

Figure 5: Second Cooldown started in June 2023

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