THE FAIR R³B PROTOTYPE CRYOGENICS CONTROL SYSTEM

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Abstract

The superconducting GLAD (GSI Large Acceptance Dipole) [1] magnet is one of the major parts of the R3B (Reactions with Relativistic Radioactive Beams) experiment. The cryogenic operation will be ensured by a fully refurbished TCF 50 cold box and oil removal system. One of the major design goals for its control system is to operate as independent as possible from the magnet control system. The cold box control system is seen as a first prototype for the later cryogenic installations in the Facility for Antiproton and Ion Research (FAIR). The operation of the compressor, oil removal system, and the gas management was successfully tested in January 2014. Within late winter 2014 a first cool-down of the refurbished cold box is planned. Once the magnet will be delivered, the magnet and the cryogenics controls will be commissioned together. To do all these learning and realization steps can be seen as preparatory work for novel industrial control systems to be established at the FAIR facility [2].

INTRODUCTION

The FAIR R^3B Prototype Cryogenics Control System comprises a fully refurbished TCF 50 cold box and an oil removal system from DESY (Deutsches Elektronen-Synchrotron).

The cold box tubing has been modified in order to meet the requirements of the cryogenic process being adapted to the GLAD magnet operation. In the refurbishing and upgrading process, an outlet was added to the shield cooling of the superconducting coil. Also all sensors and actors have been especially chosen in order to test and select possible equipment for the later FAIR installation. This included two versions of actors for the valves and passive pressure sensors which are apparently more radiation resistant. The full instrumentation of the cryo plant has been renewed and a new control cabinet replacing the previous controls has been installed.

The control system development process is following a staged implementation. First step was to understand, to design and to implement all process functionality for compressor and oil removal system inside a S7-319F with PROFIBUS and PROFINET I/O modules using WinCC OA as SCADA platform. In the second step the program logic designed in step 1 has been successfully migrated to a new version based on the CERN Unified Industrial Control System (UNICOS) framework [3]. This was the first time at GSI, that UNICOS has been used. As next steps there is the design and implementation of all algorithms and control parameters needed for the cold box processes (cool-down, shield/magnet supply and warm up) foreseen.

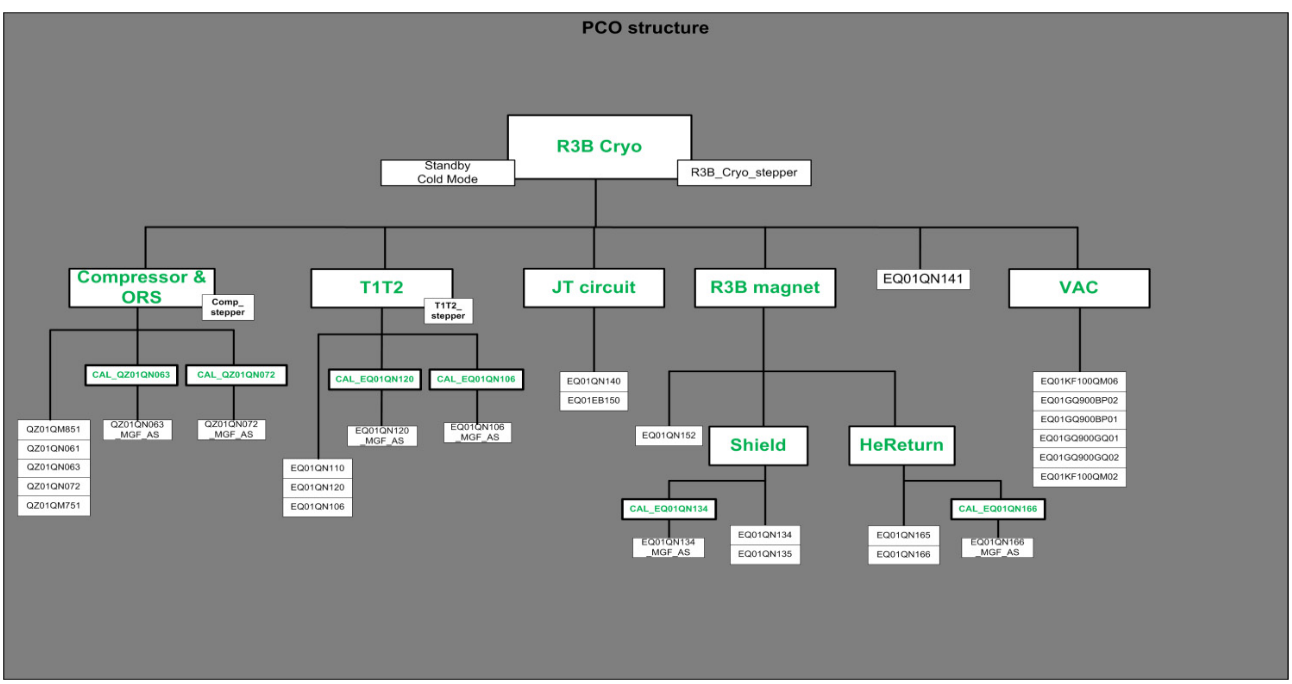

Figure 1: UNICOS unit (PCO) structure of the R^3B facility.

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METHODS

Programming Tools

To develop the R^{3}B cryogenics three-layer control system, UNICOS' Continuous Process Control (UCPC) framework is chosen for FAIR. The framework is needed additionally to the development tools of the PLC and SCADA suppliers, but the framework offers a lot of additional opportunities, which are necessary in order to deal with huge and complex installations through a small team.

For that purpose UCPC provides a set of standard objects. Those objects cover all process items, from I/O-channels to high-level compound objects like sub parts of the facility and equip them with further logic.

Next to that it is also an approach to model a process in units (IEC-61512) as well as a generic environment to develop the applications specific control logic. To develop code UNICOS provides fully object oriented tools to generate code for all basic and project specific functionalities automatically.

The code generation is based on a particular project related xml database. Inside this xml database all object relations have to be defined, together with the general features and behaviours of all needed objects, combined with the desired look and feel at the SCADA level.

The basic functionalities, which are fully implemented directly after the first automatic code generation as well for the PLC as also for the SCADA system, allow an easier commissioning phase because all devices can directly be operated from the SCADA without need of a final panel design and implementation.

After a successful commissioning of a certain unit, there is no problem to hand all code to units of the same type.

Next to automatically generated code user specific code can be added to the framework in an object orientated way, too. This code has to be inserted into allocated files, which are provided through the framework and coded in Python. These files foresee the possibility to add own PLC (e.g. SCL) code at certain places.

To generate the PLC source code and the SCADA tag database nothing else, than the project related xml database user specific code and the automatic generation tool UNICOS Application Builder (UAB) are needed.

Because there is the possibility to enlarge the system through adding additional objects or user code in several steps or iterations, the system design is exceedingly flexible.

System Network

The R^{3}B cold box can be remote-controlled via the WinCC OA SCADA system. For this purpose the S7-300 PLC is equipped with an additional network card (CP343-1 Adv.) for all communications to WinCC OA. Besides the system also can be controlled by a touch panel (TP700C), mounted on the side of the cabinet, which is connected via Industrial Ethernet to the integrated Ethernet card of the PLC.

Regarding the implementation of the control system two fieldbus systems are used in order to connect all modules and sensors: PROFIBUS for valve controllers, the Gantner remote I/O station with the main part of analogue input/output modules, the vacuum pump controller and the Janitza power analyser; and PROFINET for the Beckhoff remote I/O station, the Festo pneumatic controller station, the compressor control unit.

The large diversity of different suppliers and modules for remote I/O hardware used in the R3B cold box system comes from the idea to test them all as prospective for the FAIR cryogenic system. It is planned to focus for these systems only to PROFINET as fieldbus system and not more than two different types of remote I/O stations with a small number of different module types.

System Structure

Figure 1 shows the tree structure of the UNICOS objects of the R^{3}B cooling system. Outgoing of the root (R3B_Cryo), are several logic units/objects needed, which manage an individual task each. These units are the compressor and oil removal system, the turbines, the Joule-Thomson valve, the R3B magnet as well as the vacuum system. Related to these knots are subsidiary objects like related sub parts (heat shield/ Helium return) or valves. It is foreseen to implement at the SCADA level panels for each units of the object structure a panel which shows all related devices/objects, like it is exemplarily shown in figure 2.

UNICOS itself already provides for WINCC OA and WinCC flexible libraries in the supervision layer an interface for: import/export the configuration, all widgets (a summarized view of the object), faceplates (detailed view of the object), the trend configuration panel etc. In figure 2 is shown the control panel in WinCC OA including several widgets and as well one controller device faceplate as also the faceplate for the compressor itself.

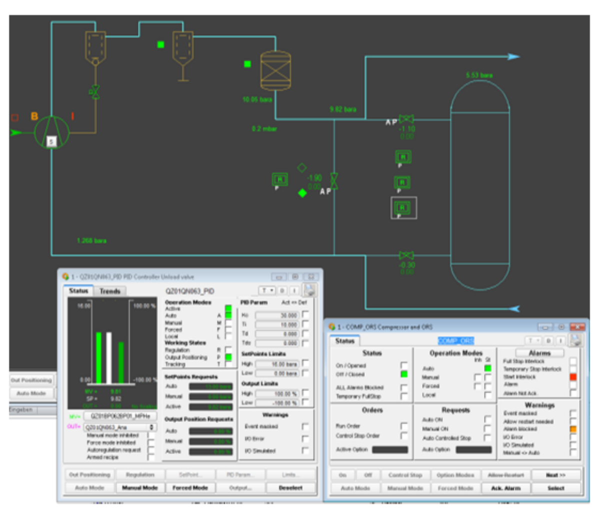

Figure 2: Control panel view developed for the R3B.

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Hardware

For data acquisition the Beckhoff PROFINET remote I/O station, especially with the analogue modules 3602 and 3612 are used in order to be tested. They have a 24 bits resolution channel, which let us have accuracy measurements with low cost, as well as to test the sensor precision.

The Festo precise proportional pressure regulators are used to control regulated valves, which are foreseen to work in environments with radiation at the FAIR facility. The idea is to replace the valve positioners through this type of subsystem. The feedback information for the position of the valve is the resistance of a potentiometer coupled to the valve axis. A limit calibration for the possible max./min. values of the resistance is made every time the system will be started to ensure the accuracy of the measurement.

Because of the low working temperatures to get liquid helium, the accuracy of the temperature measurement causes several problems. To solve them the Gantner remote I/O station with their analogue modules are used [4], the station offers the possibility to program a polynomic function in order to calculate the temperature. The sensor used to measure the temperature is a diode with a characteristic curve shown in figure 3. The calculation of the temperature is divided in two functions dependent to the input signal.

In case the input signal is bigger than 1.1135 V, in relation to temperatures equal or bigger than 30 K. The corresponding polynomial is:

$$t = f(x) = 434.17 - 363.74x$$

In case the input signal is smaller than 1.1135 V, in relation to temperatures smaller than 30 K:

$$t = f(x) = 948.02 - 2527x + 2729x^2 - 1452.3x^3 + 378.93x^4 - 38.844x^5$$

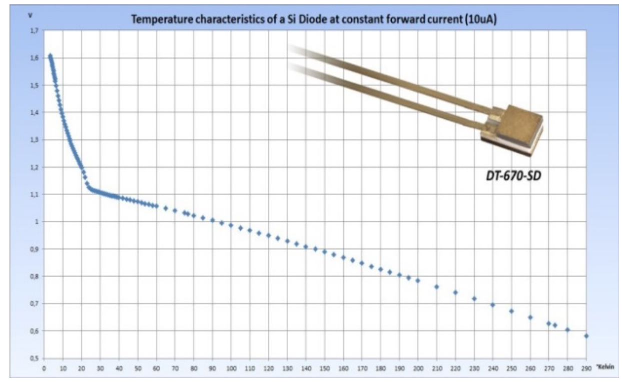

Figure 3: Diode sensor DT 670-SD characteristic curve [5].

The power analyser Janitza is to measure the performance (cooling capacity) of the complete cold box system. As soon as the system is completely cooled down, the needed electrical power for the heater of the liquid He tank inside the cold box correlates to the produced cooling capacity of the cold box system, in case the liquid helium level is stable. So the regulation of the heater is critical for the accuracy of the measurement. The signal send to the heater is monitored, the control signal is pulse-width modulated and transferred via a solid-state relay.

CONCLUSION

From the controls point of view for several problems is to show how to solve them: the accuracy the measurements needed to the process; the selection of devices according to the environment conditions at the FAIR facility; the compatibility requirements between the components of different suppliers and their availability in the market for the next years.

REFERENCES

[1] Institute of research into the fundamental laws of the universe: http://irfu.cea.fr/en/index.php
[2] H. Simon, "Status of the R³B GLAD magnet cryo plant", GSI, Germany (2014).
[3] Cern.ch, Engineering department website: https://j2eeps.cern.ch/wikis/display/EN/UNICOS
[4] Gantner-Instruments, DB.Qbloxx Modul A107-09, http://www.gantner-instruments.de/.
[5] E. Momper, Figure 3