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DEVELOPMENT OF LOW ENERGY SUPERCONDUCTING LINAC (SCL3) CONTROL SYSTEM FOR RAON*

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Abstract

The Rare isotope Accelerator complex for ON-line experiments (RAON) is under construction in Daejeon, Republic of Korea. RAON is a facility that accelerates various ions generated from ion generators such as Electron Cyclotron Resonance (ECR) and Isotope Separation On-Line ISOL) system with a superconducting linear accelerator. The low energy superconducting linac (SCL3) is composed of 22 QWR (Quarter wave resonator) cryomodules, 34 HWR (Half wave resonator) cryomodules and 56 warm sections. The cryogenic distribution system for SCL3 has 45 valve boxes dedicated for the cryomdoules. The main purpose of the SCL3 control system is integrated control and monitor of the cryomodules, the vacuum system of the warm sections and the cryogenic distribution system. SCL3 was successfully cooled down to 2K, and it is being commissioned since September 2022. This paper describes in detail the SCL3 control system developed based on Experimental Physics and Industrial Control System (EPICS) [1].

INTRODUCTION

The first purpose of the SCL3 Control System installed in the SCL3 section is to integrate and control the superconducting acceleration modules of QWR, HWRA and HWRB. The second purpose is to control the vacuum system to maintain the inside of the accelerator module and the warm section vacuum chamber in an ultra-high vacuum state. In this paper, We would like to describe the completion of the construction of the control system for integrating and operating the above three devices.

The SCL3 section consists of cryomodule, cryogenic valve box, vacuum, LLRF, tuner, magnet and beam diagnostic devices, and the control system consists of cryomodule, cryogenic valve box and vacuum chamber of warm section. Figure 1 is a block diagram of the control system, and the system is configured based on EPICS to monitor and control the devices.

- QWR : 22 Set (1 Cavity each)
- HWRA : 15 Set (2 cavities each, including bending section)
- HWRB : 19 Set (4 Cavity each)
- Warm Section Vacuum Chamber : 56 Set
- Cryogenic Valve Box : 46 Set (including 1 End Box)

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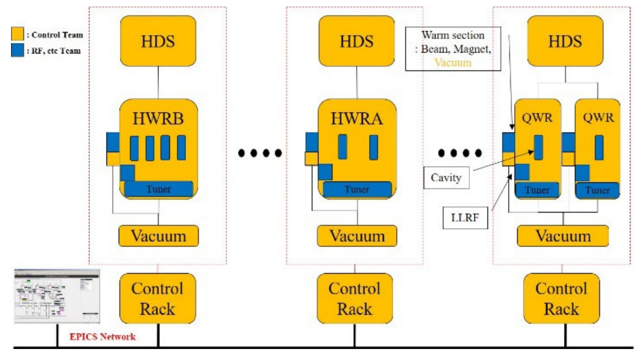

Figure 1: Control system block diagram.

HARDWARE DEVELOPMENT

The configuration of the control system for controlling the cooling and vacuum system to maintain the operating environment of the cryomodule is shown in Fig. 2.

EPICS IOC and PLC system are connected with various components to control temperature, pressure, vacuum, flow valve, etc., and are manufactured as one rack by integrating circuit breakers and power distribution devices.

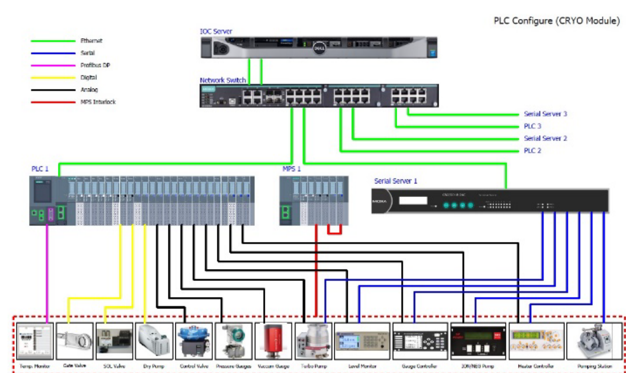

Figure 2: Control system configuration diagram.

Digital, Analog and ProfiBus Interface type components are connected to PLC, and RS-232/485 Interface type components are connected to Serial Server.

PLC and Serial Server are connected through an Ethernet switch and monitored and controlled by the EPICS IOC Server. And the EPICS IOC Server is connected to the central control system and monitors and controls remotely from the center at the same time as collecting data.

As shown in Fig. 3, The layout of the control system rack installed in the SCL3 section, and it consists of a total of 45 sets including the bending section.

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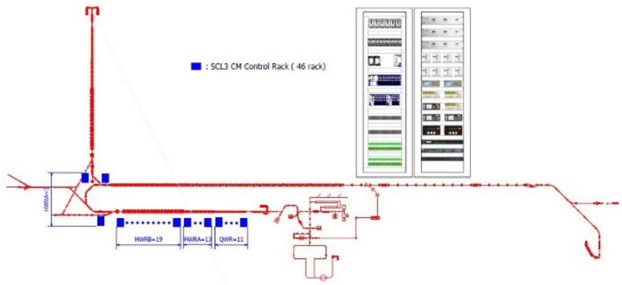

Figure 3: Rack layout of SCL3 section.

The Control System Rack is shown in Fig. 4. It is manufactured as a PLC Rack for power supply and circuit breaker and a Monitor Rack for various monitors and control devices.

Figure 4: Control system rack configuration.

SOFEWARE DEVELOPMENT

The heavy ion accelerator uses EPICS (Experimental Physics and Industrial Control System) as a software framework to integrate the environment of distributed devices. EPICS is middleware for distributed control including Ethernet communication layer inside.

The Field instrument I/O signals of the control system can be collected from the PLC and transmitted to the EPICS IOC, which is connected to the upper main control system through the EPICS control network.

EPICS I/O signal PV (Process Variable) of each local device connected to the main control system enables monitoring and control of data through an integrated GUI screen composed of CSS (Control System Studio). Also, time-stamped I/O signal data can be saved or extracted and displayed through the EPICS Archive Appliance. In addition, Alarm information can be stored and managed in CSS through Alarm setting in EPICS DB.

Software information is as follows.

- OS : Debian 8.x 64 bit
- EPICS Base : 7.0.5
- Asyn Driver : asyn-4-26
- SIENENS PLC : modbus-R3-0
- CSS : CS-Studio-raon 4.4.2

EPICS IOC

As shown in Fig. 5, the software is configured, and the I/O signals collected from PLC and monitoring devices are made in the form of IOCs that can be used in the EPICS environment.

The control system adopts an industrial PLC whose reliability has been proven to operate stably in a harsh environment in order to control the temperature, pressure, vacuum, flow rate and valves of the device. And the code developed by PLC converts I/O signals collected from field components into valid variables into a DB and transmits them to EPICS IOC Server via Ethernet Switch.

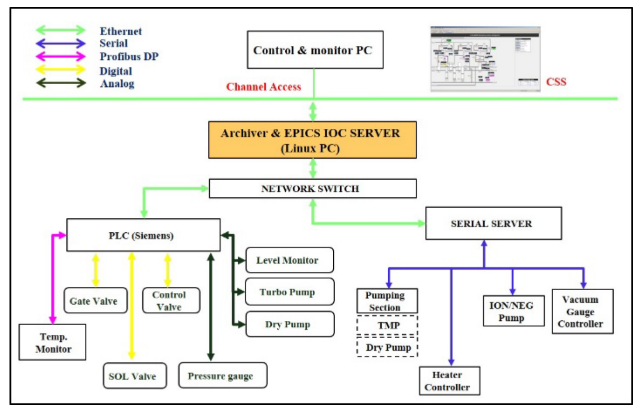

Figure 5: Control system software block diagram.

PLC

As shown in Fig. 6, the PLC converts electrical signals from various sensors and actuators configured of devices into engineering physical quantities suitable for the properties of each material and converts them into information. The collected and processed physical information is transmitted and integrated to the upper control frame, EPICS, in the form of DB through logic implementation.

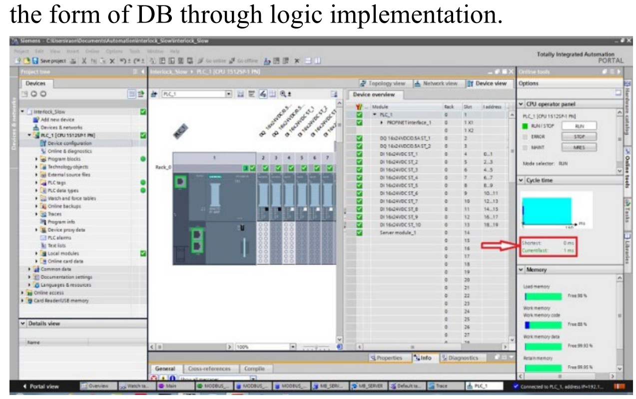

Figure 6: PLC Logic.

CSS

Devices and equipment integrated by EPICS are designed to check and control the status of temperature, vacuum, pressure, valves, etc. of each module and valve box system through CSS, as shown in Fig. 7.

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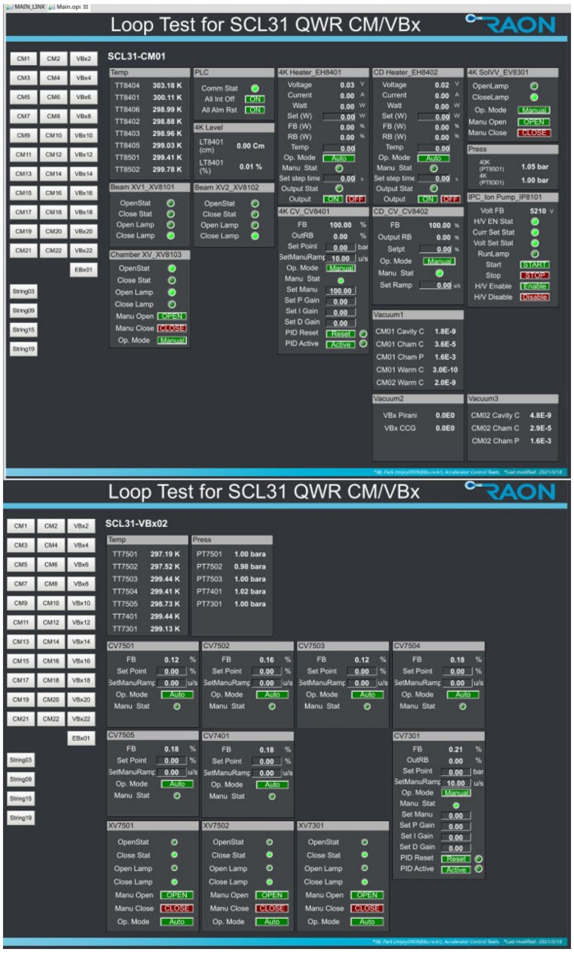

Figure 7: Cryomodule and Valve-Box control screen.

As shown in Fig. 8, in the case of String Vacuum, a screen that can individually check the vacuum level and monitor and control related valves and pumps is configured and operated.

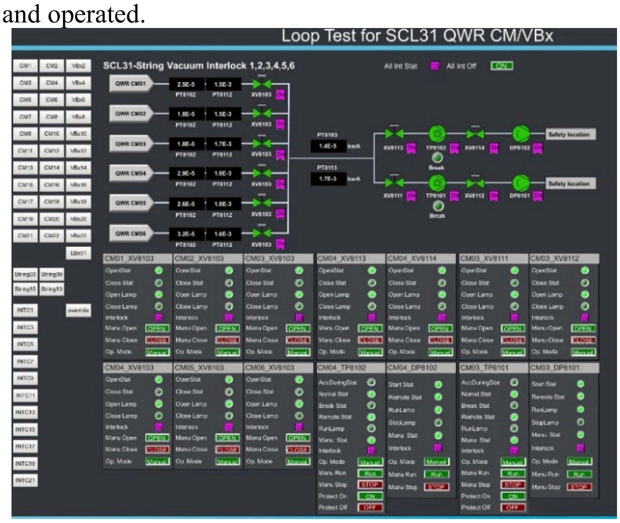

Figure 8: Vacuum string related control screen.

The interlock consists of an individual operation screen that applies the override function, and a local interlock and global interlock control screen for modules and valve boxes.

Alarm and Interlock

A control system for alarm and interlock was developed. Most actuator interlocks use a PLC-based local interlock method in order to reduce risk factors due to fast operation and network instability. In the special case of mode-specific interlock and global interlock, the interlock control system is implemented with EPICS-based softIOC. Alarm is implemented by adding alarm PV to EPICS IOC [2].

The interlock logic test is performed using the established control system. Create interlock conditions by setting virtual signals, comparison values, timers, etc. in CSS and monitor the operation of actual devices. Through this, the integrity of the interlock logic and control system was confirmed.

CONCLUSION

In July 2022, the performance test of QWR, HWRA, HWRB, and P2DT was conducted with the control system built in SCL3, and data was acquired as shown in Fig. 9, and devices were successfully controlled and monitored.

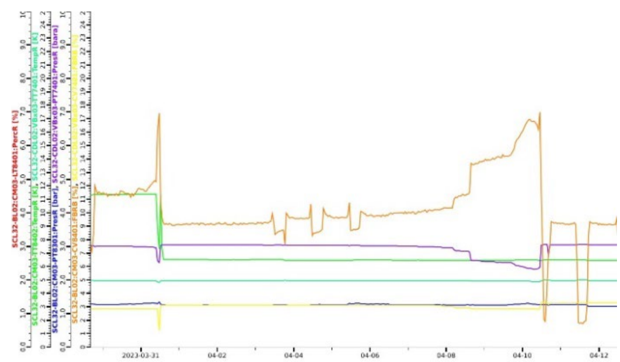

Figure 9: Data Browser screen (HWRA CM03).

Currently, in order to transmit beams to KOBRA (KOrea Broad acceptance Recoil spectrometer and Apparatus), a low-energy test facility, performance tests of the injector, SCL3, and P2DT devices are being conducted remotely from the central control center, as shown in Fig. 10.

Figure 10: Central control centre.

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