Controls and Monitoring Screens for the Cryo Control Reservoir's Instrumentation of the SoLID Solenoid

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This note describes the development of the Human Machine Interface (HMI) and Control System Studio Best OPI Yet (CSS-BOY) screens to control and monitor the Cryo Control Reservoir (CCR) instrumentation.

The CCR is the junction between the end station refrigerator (ESR) and the solenoid. Cryogens pass through the CCR before they enter or exit the solenoid. There are two reservoirs inside the CCR, one stores liquid nitrogen (LN_2) and the other liquid helium (LHe). To allow the control of the cryogens, the CCR houses Joule Thomson (JT) valves, relief valves, vacuum gauge, pressure transducers, liquid level probes, and temperature sensors.

Control of the proportional–integral–derivative loops of the JT valves and monitoring of the temperature sensors is done by the PLC system [1]. Data are transferred to the HMI and EPICS system. The CCR screens control the supply and return of LN_2, which cools the solenoid's radiation screen from 300 K to 80 K, and LHe, which cools the coils from 80 K to 4.5 K [2].

The HMI screen, Fig. 1, is based on the piping and instrumentation diagram of the CCR; the screen provides an overview of the LN_2 and LHe flow circuits. The CSS-BOY screen, Fig. 2, is based on the HMI screen. The HMI screen was developed with FactoryTalk View Studio software [3] and the CSS-BOY screen uses Control System Studio software [4].

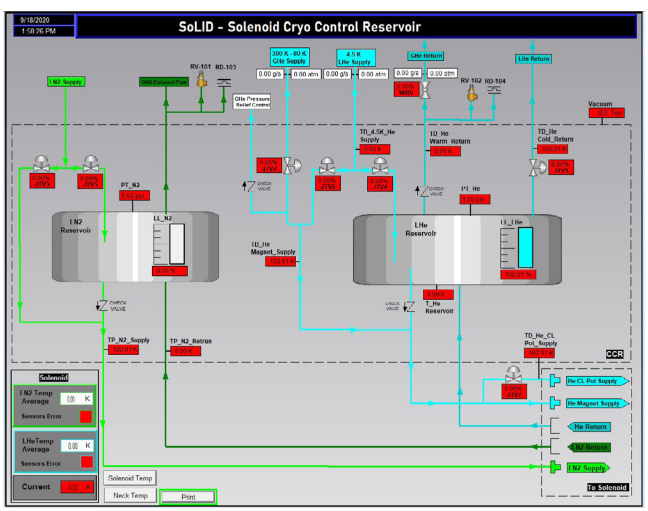

FIG. 1. Cryo Control Reservoir HMI screen. Red indicators show PLC channel faults, caused by the disconnect of temperature, liquid level, pressure, vacuum, and macro sensors to the PLC.

Indicators in the upper section of the screen monitor warm helium supply flow rate and pressure, cold helium supply flow rate and pressure, and helium gas (GHe) return flow rate and pressure. Helium has two supply lines—a GHe supply (300 K–80 K) and LHe supply (4.5 K)—and two return

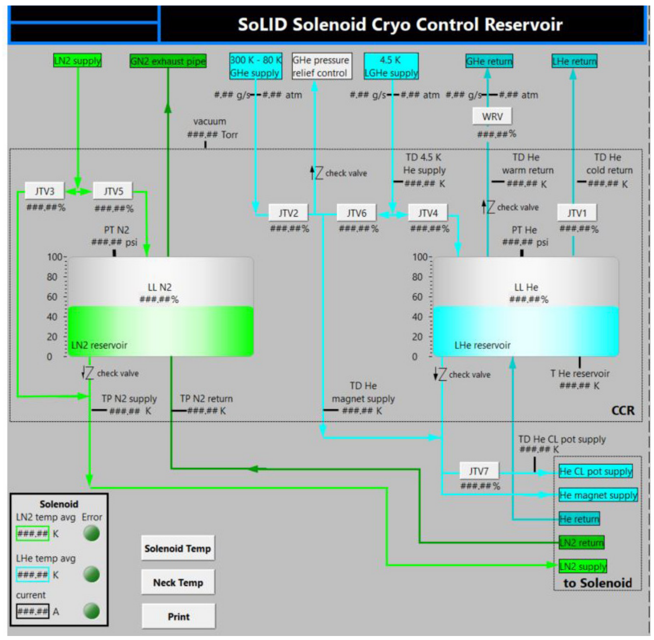

FIG. 2. Cryo Control Reservoir CSS-BOY screen.

lines—GHe return and LHe return.

There is one LN_2 supply line and one nitrogen gas (GN_2) return line. There are indicators for the liquid level probe that measures the LN_2 level inside the reservoir and the pressure sensor that reads the pressure inside the reservoir. Also, there are two indicators that monitor the LN_2 supply and return temperatures.

Five JT valves—1, 2, 4, 6, 7—and one ball electric valve, WRV, control the flow of helium. Table I shows the list of JT valves that control supply and return of helium and nitrogen.

Valve	Cryogen controlled
JTV1	cold LHe flow return from CCR to ESR
JTV2	direct inlet of GHe supply to solenoid
JTV3	direct inlet flow of LN_2 to radiation screen
JTV4	inlet LHe flow supply to LHe reservoir
JTV5	inlet LN_2 flow to LN_2 reservoir
JTV6	direct inlet of LHe supply to solenoid
JTV7	LHe flow through solenoid's current leads
WRV	GHe flow return from CCR to ESR

TABLE I. Cryo Control Reservoir valve list.

Six diode temperature sensors on the screen measure the temperatures for the helium circuit, Table II.

Temperature sensor	Temperature measured
TD_He_Magnet_Supply	helium supply at inlet of solenoid
TD_He_4.5K_Supply	cold helium supply from ESR to solenoid and LHe reservoir
TD_He_Warm_Return	warm helium return from CCR to ESR
TD_He_Reservoir	LHe reservoir
TD_He_Cold_Return	cold helium return from CCR to ESR
TD_He_CL_Pot_Supply	helium supply in solenoid's current leads pot

TABLE II. List of CCR temperature sensors.

Indicators for the pressure and liquid level probe are installed inside the LHe reservoir to measure pressure and liquid levels, respectively. A screen indicator monitors the vacuum in the CCR.

All JT valve symbols on the HMI screen and labeled rectangles on the CSS-BOY screens are programmed with touch animation to allow the user to navigate to a separate pop up screen, which controls the valve parameters at the expert level. Additionally, each valve image/rectangle is configured with two colors. Green indicates an open valve (% of valve LVDT readout > 0), and gray indicates a closed valve.

In the lower left section of the screen, average LHe temperatures, average LN_2 temperatures, and the solenoid's power supply current value are shown.

For the LHe, the average is calculated from 18 temperature sensors readings. Fourteen sensors are located in the solenoid coil shell and four are located in the solenoid neck.

For the LN_2, the average is calculated from nine temperature sensor readings. Seven sensors are located in the solenoid radiation screens (inner and outer) and two sensors are located in the neck.

Each indicator on the screen is configured with color animation to alarm in case of failure. All indicators blink red when there is a fault in the sensor or a fault in the PLC ADC channel.

Two navigation buttons allow access to the solenoid temperatures screen [5] and neck temperatures screen [6]. The Print button enables a screenshot.

The HMI screen was tested by reading the actual values from the PLC in running mode since the HMI system is linked with the PLC. All variable values and faults are read from the PLC and can be monitored in real time in the HMI screen. To test fault conditions, test PLC tags are used and their values can be changed without affecting the system. Indicators' values, blinking features, screen formatting, and navigation buttons were tested by running FactoryTalk SE Client, which connects to the developed HMI server and allows real time monitoring. The CSS-BOY screen was tested by using local process variables generated by a script that runs in the CSS environment [7].

The Cryo Control Reservoir HMI and CSS screens are completed.

[1] P. Campero, *Hall A SoLID Magnet PLC Control System*, DSG Talk 2020-12, 2020.

[2] Oxford Instruments LTD, *Operating Manual for Cleo II Super Conducting Magnet*, Oxford England, 1987.

[3] P. Campero, et al. *Steps to Install and Run the HMI System,* DSG Note 2020-21, 2020.

[4] M. A. Antonioli, *Generating CSS-BOY Screens*, DSG Talk 2020-20, 2020.

[5] P. Campero, et al. *HMI and CSS-BOY Screens for SoLID Magnet Coils and Radiation Shield Temperatures,* DSG Note 2020-25, 2020.

[6] P. Campero, et al., *Controls and Monitoring Screens for SoLID Solenoid Neck Temperatures,* DSG Note 2020-26, 2020.

[7] T. Lemon, et al., *Test Operator Interface Creator Program,* DSG Note 2020-23, 2020.