Expert Controls and Monitoring Screens for the Radial and Axial Supports of the SoLID Solenoid

Pablo Campero and Mary Ann Antonioli, Peter Bonneau, Aaron Brown, Brian Eng, George Jacobs, Mindy Leffel, Tyler Lemon, Marc McMullen, and Amrit Yegneswaran
Physics Division, Thomas Jefferson National Accelerator Facility, Newport News, VA 23606
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This note describes the features and the development of Human Machine Interface (HMI) and Control System Studio Best OPI Yet (CSS-BOY) screens, which control and monitor load sensors located in the radial and axial supports of the solenoid.

As part of the general interlock system, monitoring compression and tensile forces over the coil shell and the radiation screen is critical to prevent mechanical damage [1]. Strain gauge load sensors measure forces in the radial supports and load cell sensors measure forces in the axial supports [2]. These force measurements indicate movement of the coil shell, the radiation screen, or both.

The PLC of the solenoid [3] constantly monitors the readings of the strain gauge load sensors and the load cell sensors. The monitored values are compared to the two-level thresholds that are based on design specifications. If a load value is above its limit, one of the two types of interlocks is activated.

The controlled ramp interlock generates a controlled ramp down of the solenoid's current by sending a command to ramp the current down to zero to the magnet power supply. The fast dump interlock triggers a fast dump of the solenoid's current by opening the dump contactor in the magnet power supply.

The HMI screen, Fig. 1, was developed first; the CSS-BOY screen, Fig. 2, is based on the HMI screen [4]. Both screens are similar in appearance and have the same monitoring and control options. FactoryTalk View Studio software was used to generate the HMI screen [5], Control System Studio software for the CSS-BOY screen.

Both the HMI and CSS-BOY screens have two sections—the upper section with the Radial Supports information and the lower section with the Axial Supports information. The first column contains the strain gauge load sensor or the load cell sensor labels, the original names issued by Oxford Instruments.

Sensor readout values are in the second column. Each indicator on the HMI screen shows the value of a PLC tag associated with a sensor. Indicators on the CSS-BOY screen show the values of the EPICS process variables, which are associated with the PLC tags of the HMI screen.

The Controlled Ramp Threshold, column three on the screen, allows input of an integer number for the threshold value, which is transferred to the PLC program and then compared to the radial or the axial load readout value. If the readout value is greater than the controlled ramp threshold value and the interlock is enabled, the PLC enables a 30 s timer. Once thirty seconds have elapsed, the logic triggers a command to set the magnet power supply's current to 0.00 A at a fixed ramp rate.

The Fast Dump Threshold input parameter, column four, is used to set a value that is compared to the radial or axial load readout value. If the readout value is greater than the fast dump threshold value and the interlock is enabled, then the

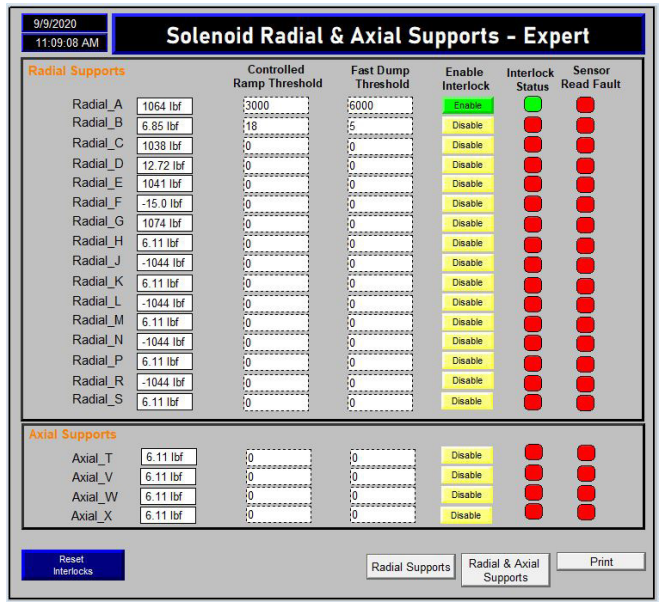

FIG. 1. Radial and Axial Supports Expert HMI screen. Red indicators show PLC channel faults, since strain gauge load sensors and load cell sensors are not currently connected to the PLC. The green interlock status indicator results from below threshold testing of the current load of radial support Radial A.

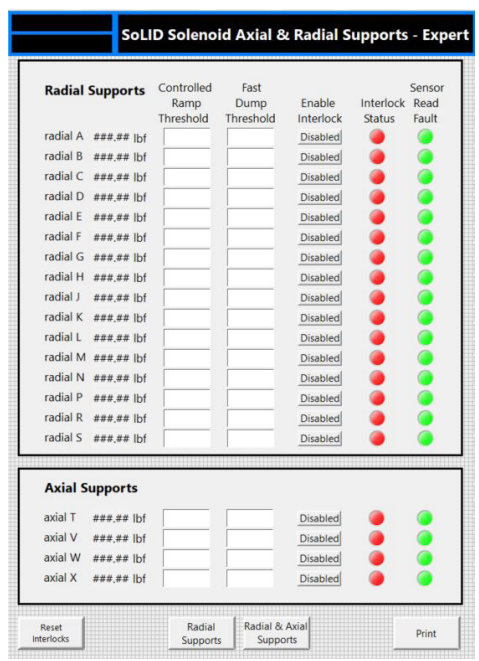

FIG. 2. Axial and Radial Supports – Expert CSS-BOY screen.

PLC logic enables a 5 s timer; at the end of the five seconds a PLC relay channel is enabled to open the magnet power supply's dump contactor and fast dump the current.

The Enable Interlock buttons in column five are Boolean buttons that allow the expert to enable the interlock for each sensor. When the button is green, the interlock is enabled, allowing a controlled ramp down or a fast dump of the magnet. A yellow color indicates that the interlock is disabled, thus no controlled ramp down or fast dump of the magnet will be initiated. This enable/disable option helps to avoid controlled ramp downs or fast dumps in case of a faulty or a dead sensor with readout values always out of limits.

Interlock Status Boolean indicators, column six, show the status for each axial or radial load interlock. Green means no interlock is activated—the readout value for the sensor is below the controlled or the fast dump threshold. Red means that the interlock has been activated and the power supply could be ramping down or fast dumping.

The last column of Sensor Read Fault indicators allows monitoring of sensor status. Green indicates a load sensor is within parameters and the ADC module channel used to read the sensor has no faults. Red indicates a fault in the sensor, the ADC channel, or both. Indicators are configured to blink red when a sensor fault is present.

The screens have two navigation buttons located at the bottom—the Radial Supports button opens the Radial Support screen and the Radial & Axial Supports button opens the Radial & Axial Supports screen [6].

The Reset button in the bottom left corner of the screens clears latched interlocks as long as there are no faults and the sensors read values are within their limits.

The Print button at the bottom right allows a screenshot to be taken with the current values, a feature which can be useful during debugging.

The HMI and CSS screens' testing was performed independently. The HMI screen was tested by reading the actual values from the PLC in running mode, which is possible since the HMI system is linked with the PLC. To test errors and interlocks, test tags are used whose 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 HMI server and allows real time monitoring.

The CSS screen was tested using local process variables generated by a script that runs in the CSS environment [7].

The Expert HMI and CSS screens for the solenoid radial and axial supports are ready to be implemented.

[1] Y. Kubota, et al., *The Cleo II Detector*, Elsevier Science Publishers, 1992.

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

[3] P. Campero, et al., *Hall A: PLC Controls System for SoLID*, DSG Talk 2020-12, 2020.

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

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

[6] P. Campero, et al., *Controls and Monitoring Screens for the Axial and Radial Supports of SoLID's Solenoid,* DSG Note 2020-27, 2020.

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