Temperature Controls and Monitoring System for the Hall A SoLID Solenoid

Pablo Campero, 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 temperature controls and monitoring, and archiving, system developed for the Hall A solenoid.

The hardware components for temperature controls and monitoring, and archiving, are based on a PLC control system with a 1756-L72 Contrologix controller [1], Fig 1.

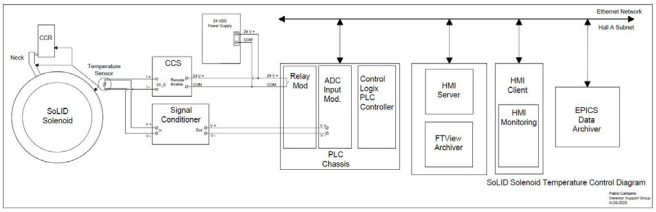

FIG. 1. Diagram shows the hardware and software components for controls and monitoring, and archiving.

The software components are RS-Logix 5000 to program the PLC controller to read the temperature sensor values, FactoryTalk View Studio to create the Human Machine Interface (HMI) screens, alarm, and archiving systems [2], and EPICS to monitor and archive the temperature values transferred from the PLC control system.

To monitor the temperatures, four-wire rhodium-iron, four-wire diode, and four-wire PT-100 temperature sensors are located on the solenoid, Cyro Control Reservoir (CCR), and heat exchanger. The temperature sensors will be powered by constant excitation current from the constant current supply (CCS) boards [3] powered by a 24 VDC power supply controlled by the PLC relay module. A single temperature sensor will be connected to each CCS board channel. All temperature sensors will be read by a 1756-IF16 ADC module and the Allen Bradley 1756-L72 PLC controller.

Since the PLC ADC modules to read the temperature sensors will be located in Hall A's counting house (~150 ft. from the temperature sensors), a Dataforth signal conditioning module will be located between the temperature sensor and the PLC ADC module to filter, isolate, and convert the input signal to a high level analog voltage output (amplification factor of 10^3).

Table I shows all temperature sensors that are monitored and controlled in the solenoid, CCR, and heat exchanger. There are 21 sensors installed on the solenoid in three areas: inner radiation screen, outer radiation screen, and coil shell [4]. Eleven sensors are installed on the neck of the solenoid [5]. Names and locations for the solenoid's sensors are based on information provided by Oxford Instruments [6]. Ten sensors are installed in the CCR to control and monitor temperatures of the inlet and outlet of cryogens to the solenoid

Sensor name	Sensor location
TS1	magnet - coil shell
TS2	magnet - coil shell
TS3	magnet - coil shell
TS4	magnet - coil shell
TS5	magnet - coil shell
TS6	magnet - coil shell
TS21	magnet - coil shell
TS22	magnet - coil shell
TS23	magnet - coil shell
TS24	magnet - coil shell
TS25	magnet - coil shell
TS26	magnet - coil shell
TS33	magnet - coil shell sorbs
TS34	magnet - coil shell sorbs
TS29	magnet - outer radiation screen
TS30	magnet - outer radiation screen
TS31	magnet - outer radiation screen
TS32	magnet - outer radiation screen
TS11	magnet - outer radiation screen
TS12	magnet- inner radiation screen
TS13	magnet- inner radiation screen
TS7	magnet neck - helium supply pipe
TS8	magnet neck - helium supply pipe
TS27	magnet neck - current lead cold end neg.
TS28	magnet neck - current lead cold end pos.
TS9	magnet neck - LN_2 supply pipe
TS10	magnet neck - LN_2 return pipe
AST1a	magnet neck - LN_2 supply pipe
AST2	magnet neck - LN_2 return pipe
CU1	magnet neck - supply helium pipe
CU2	magnet neck - return helium pipe
AST4	magnet neck - return helium pipe
PT_LN_2_ Supply	CCR - LN_2 supply pipe
PT_LN_2_Return	CCR - LN_2 return pipe
TD_He_Magnet_supply	CCR - helium magnet supply pipe
TD_He_4.5K_supply	CCR - cold helium supply pipe
TD_He_Cold _Return	CCR- cold helium return pipe

TD_He_Reservoir	CCR- helium reservoir
CL_L Temp Warm	CCR- current lead warm end neg.
CL_R Temp Warm	CCR- current lead warm end pos.
TD_GN2_HX_exhaust	heat exchanger - GN_2 exhaust pipe
TD_Ghe_Mix	heat exchanger - GHe outlet mixing line

TABLE I. Solenoid (coil shell, radiation screen, neck), CCR and heat exchanger temperature sensors list.

[7]. Two temperature sensors are installed in the heat exchanger to monitor nitrogen exhaust and mixed helium gas at the outlet of the heat exchanger.

For calibration, resistance vs temperature curves added in the PLC code enable precise temperature readout, which is performed constantly. The PLC ADC module used is a 16-channel, single-ended, 0–5 V configuration that allows real time sampling of up to 62 samples per second.

Another PLC routine allows remote enabling and disabling of power to the sensors. When enabled, the 1756-OW16I PLC relay channel is closed and a 24 VDC signal is sent to the CCS board, which then supplies the excitation current to the temperature sensors. Additionally, the PLC routine detects readout errors for each channel, aiding debugging in case a sensor fails.

To facilitate the visual location of the temperature sensors on the solenoid, three-dimensional models have been developed with NX 12 software [8].

To monitor temperatures in the solenoid and the CCR, three HMI and three CSS screens were developed—Coil Shell & Radiation Screen Temperatures, Neck Temperatures, and CCR. The PLC is connected to the HMI server and all temperature signals are transmitted to the server in real time. HMI screens have the capability to change indicator colors when alarms are present, and screens will have navigation options to open trend screens, which will show changes in temperature of each sensor over time. Several clients can connect to the HMI server and run the HMI screens simultaneously to monitor the temperatures of the solenoid.

A data archiver based on FactoryTalk View system was developed to archive temperature signals. Additionally, the PLC will send all signals to be archived to the accelerator division's EPICS archiver.

Temperature controls and monitoring based on a PLC system has been developed and is ready to be implemented.

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

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

[3] M. McMullen, et al., *Constant Current Source Printed Circuit Board,* DSG Note 2020-07, 2020.

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

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

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

[7] P. Campero, et al., *Controls and Monitoring Screens for the Cryo Control Reservoir's Instrumentation of the SoLID Solenoid*, DSG Note 2020-33, 2020.

[8] P. Campero, et al., *Two-dimensional and Three-dimensional Models of SoLID Magnet's Structural Components,* DSG Note 2020-24, 2020.