Controls and Monitoring System to Power Up the Hall B Solenoid

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This note describes the controls and monitoring system used for the power up of the Hall B superconducting Solenoid magnet.

The controls and monitoring hardware comprises an Allen Bradley PLC, two NI cRIOs, and hardware controllers—Excitation Chassis, Quench Detectors (QD), vacuum pumping system, and Cryocon temperature monitors, Fig. 1.

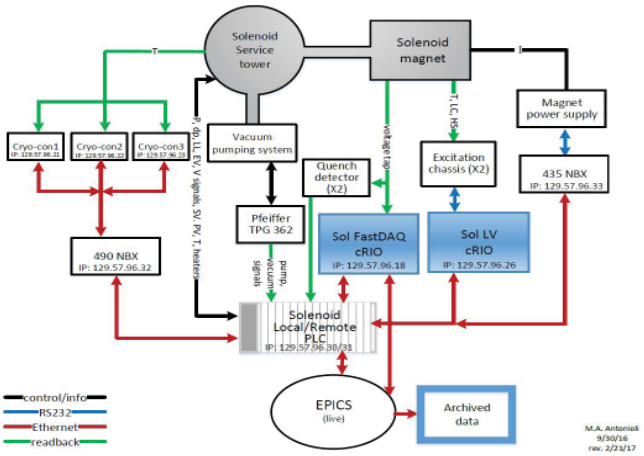

FIG. 1. Communications and controls and monitoring system of Solenoid magnet.

The PLC's two A-10 chassis, local and remote, house a 1756-L72 controller, analog input (AI), analog output (AO), and Ethernet (ENT) modules; and relay output (RO), digital input (DI), sequence of event (SOE), and ENT modules, respectively.

AI/AO modules read and control signals from pressure transducers, heaters, liquid levels, valve position in the cryo reservoirs, mass flow controllers, and vacuum signals. DI modules read back the status of QDs, heater controllers, valves, interlock event timestamps, and the bipolar Danfysik magnet power supply (MPS). RO modules control electric and pneumatic valves, heaters, and MPS resets. ENT modules share process variables via the Hall B subnet with the Torus and the Distribution Box PLCs.

The Solenoid PLC program was developed in Studio 5000 Logix Designer software, version 27.0, and runs independently on the controller, handling cooldown, energization, vacuum conditions, and interlocks systems. After analysis, it transmits data to EPICS for display and archiving by Mya archiver, and if needed, initiates control actions or responds to control requests from EPICS.

The Fast Dump Hardwire, PLC Fast Dump, and PLC Controlled Ramp Down interlocks, Fig. 2, protect the Solenoid.

The Fast Dump Hardwire interlocks' signals, generated by RO of hardware controllers or RO of the PLC hardware watchdog, are hardwired to interlock relays. Thresholds for output of interlock signals are defined in the devices; hence, there is no software intervention for initiated control action. The SOE module monitors all eleven hardwired interlock faults with an event detection precision of 25 µs.

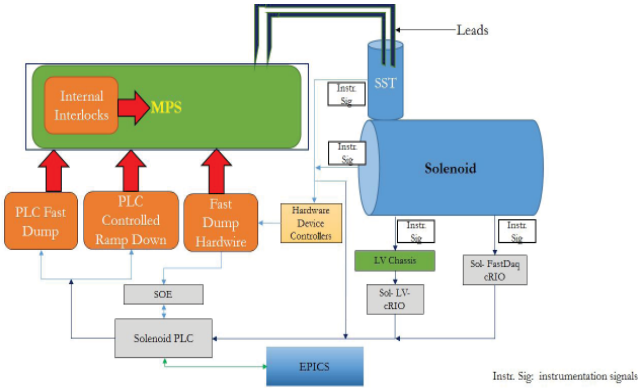

FIG. 2. Interlock systems process diagram.

The program *Magnet Interlocks* (within the Solenoid PLC program) resides in the PLC controller and enables setting of thresholds, delays, and ramp down initiation for PLC Fast Dump and PLC Controlled Ramp Down interlocks. PLC Fast Dump interlocks are generated in the PLC from higher overthresholds of signals that are considered critical during ramp up of the Solenoid—voltage tap signals, load cells, EPICS button signals, and current limit. PLC Controlled Ramp Down interlock are generated in the PLC as a result of overthreshold of cryo, vacuum, load cells, voltage taps, and current limit signals.

Fast Dump Hardwire or PLC Fast Dump interlocks initiate MPS ramp down by opening the dump contactor; at full current of 2416 A, de-energization of Solenoid takes ~145 s. PLC Controlled Ramp Down interlocks initiate a controlled ramp down that takes ~70 minutes for de-energization.

PLC routines communicate with the MPS via RS232; internal interlock status, reset interlocks status, power on/off, and set/readback current are read remotely.

To prevent damage to coils, leads, bobbins and splices, current readout is compared continuously to the thresholds. A PLC Fast Dump event is initiated if an overcurrent of either negative or positive polarity is detected.

Quench detection events are monitored by software and are controlled by QDs; 60 mV and 100 mV thresholds are used for all channels of the two QDs, which generate a PLC Fast Dump interlock.

PLC routines monitor data from load cells, eight each for axial and radial supports, and calculate unbalanced forces in the radial and axial directions. Data and forces are compared to two levels of thresholds. Lower thresholds initiate a PLC Controlled Ramp Down event; the upper a PLC Fast Dump event.

During energization, cryogenic and vacuum conditions are monitored continuously to avoid overheating. Thresholds are set to check overpressures, vacuum levels, low liquid level in the Lead and Magnet reservoirs, flows, and voltage drops and temperature in the leads. If any of the thresholds are exceeded, a PLC Controlled Ramp Down event is generated.

To ensure safety, prior to energization, checkout procedures B000000400-P003 (checks proper functioning of sensors and instrumentation and records values) and B000000400-P005 (checks all interlocks) are completed.

To conclude, a control and monitoring program was designed and developed to ensure safe Solenoid energization. The Solenoid was successfully energized in July 2017.