Hall A SoLID Magnet PLC Control System

Pablo Campero
Detector Support Group
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PLC Controls Overview

SoLID PLC
primary and
secondary
PLC I/O chassis
remote 1 and 2

HMI monitoring
FTView data archiver
OPC server
EPICS data archiver

Flex bus 1794 ACN15 w/ Prosof MV194 ASCII mod.

HMI
monitoring
FTView data
archiver
OPC server
EPICS data archiver

Solenoid Control System, M. A. Antonioli, 6/9/2020
Selected an Allen Bradley ControlLogix 1756-L72 controller, with the following specifications:

- User memory: 4 MB
- I/O memory: 0.98 MB
- Optional non-volatile memory: 1 GB
- Chassis: 1756-A6
- Communication option: EtherNet/IP and ControlNet
- Controller redundancy: full support

Note: Currently SoLID PLC system is using a 1756-L62 Hall C spare controller
• Redundancy system allows switchover between primary and secondary PLC chassis, if primary chassis has one of these conditions:
  – Loss of power
  – Major fault on controller
  – Removal or insertion of any module
  – Failure of any module
  – Damage to a ControlNet cable
  – Loss of EtherNet/IP connection
  – Program-prompted command to switch over
  – Command that is issued via Redundancy Module Configuration Tool

• After switchover occurs, new primary controller continues to execute programs, which begins with highest-priority task that had been executing on previous primary controller
PLC System Layout

SoLID magnet PLC layout
PLC System Layout

- Two PLC chassis with identical controllers and communication modules
  - **Primary and Secondary:** PLC controller, Ethernet, ControlNet, redundancy modules
- Two Remote I/O PLC chassis
  - **Remote #1:** Digital input (x1), analog input (x5), analog output (x1), relay (x2), and ControlNet (x1) modules.
  - **Remote #2:** Analog input (x3), relay (x1), and ControlNet (x1) modules

Current setup of SoLID PLC chassis located in TED 1544
PLC Controls Program Overview

- Hall A SoLID PLC will be based on Hall C’s HMS main program with eight PLC routines to perform (CLEO routine has 57 sub-routines/sheets):
  - Sensor controls and readout
  - Instrumentation control and monitoring
  - Monitoring of axial and radial supports
  - Power supply control and monitoring
  - Cooldown operations and interlocks
  - Magnet power up/down operations and interlocks

Current setup of SoLID PLC program, based on Hall C HMS
PLC Controls Program Status

• Modification for PLC chassis remote #1 – **Completed**
  – IF16 PLC module was changed from its single mode to differential mode
  – New channel assignment for I/O modules

• Addition of PLC chassis remote #2 – **Completed**
  – Added three 1756-IF16 analog input modules to readout temperature sensors, LVDTs, and heat exchanger instrumentation
  – Added 1756-16OWI relay module to control JT valves’ motor boards
  – Configured I/O modules based on latest PLC layout– **Completed**
    ▪ Added additional modules to PLC program to inhibit faults so PLC programming modification continued
PLC Controls Program Status

• PLC code completed for:
  – Read 32 temperature sensors in magnet radiation shield, coils and neck
    ▪ Calculate max, min, average for temperature values
    ▪ Error/faults handler
    ▪ Read out eight temperature sensors located in Cryo Control Reservoir (CCR)
  – Read 16 radial (strain gauges) and four axial (load cells) supports
    ▪ Calculate max, min, average for load cells and strain gauges
    ▪ Error/faults handler
  – Control and monitor LN$_2$ and He pressure sensors
  – Control Constant Current Source (CCS) boards enabling/disabling
    ▪ CCS boards are used to provide excitation current for all temperature sensors
• PLC code completed for:
  – Read eight LVDTs to determine position of JT valves located in CCR
    ▪ Errors/fault handler
  – Vacuum gauge readout, controls, and interlock logic
    ▪ Faults and levels based on Hall C HMS
  – Read hall probe
  – Control and monitor heat exchanger instrumentation
    ▪ Temperature sensors readout
    ▪ LVDT readout and error handler for LN$_2$ and GHe mix JT valves
PLC Programming Status – Cont’d

• PLC code in progress
  – Controls and monitoring of liquid levels in CCR
    ▪ Liquid level probes and monitors have not been defined
    ▪ Suggested liquid level monitors LM-510, which has dual sensor
  – Communications with magnet power supply
    ▪ PSU needs to be defined and based on specs, program could change
  – Heat exchanger JT valves PID controls
    ▪ Need to define operation conditions to control valve opening/closing
    ▪ Confirm temperature sensors to calculate temperature differential
    ▪ Radial strain gauges and radial load cell look-up table implementation
    ▪ Need to check specs provided
# PLC Tasks Tracking

Detector Support Group (DSG) spreadsheet allows tracking of PLC programming progress.

<table>
<thead>
<tr>
<th>Task #</th>
<th>Description</th>
<th>Able to Proceed?</th>
<th>Start</th>
<th>Finish</th>
<th>Assigned Person</th>
<th>Status</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Instrumentation readout (LL, PT,MFC)</td>
<td>Yes</td>
<td>04/14/20</td>
<td></td>
<td>Pablo</td>
<td>In Progress</td>
<td>Readout for liquid levels for N₂ and He completed Readout for pressure sensors completed</td>
</tr>
<tr>
<td>1.2</td>
<td>Sensors readout (temp, Load cells, Strain, hall sensors)</td>
<td>Yes</td>
<td>02/10/20</td>
<td>05/20/20</td>
<td>Pablo</td>
<td>Completed</td>
<td>Completed PLC routine to control and monitor temperature sensors in the magnet radiation screens, coil shell, neck and CCR. Completed supports readout. Need to enter look up tables</td>
</tr>
<tr>
<td>1.3</td>
<td>Vacuum gauge readouts, controls and interlocks logic</td>
<td>Yes</td>
<td>04/10/20</td>
<td>04/13/20</td>
<td>Brian</td>
<td>Completed</td>
<td>Fault levels same as SHMS/HMS</td>
</tr>
<tr>
<td>1.4</td>
<td>Heat Exchanger instrumentation control</td>
<td>Yes</td>
<td>01/15/20</td>
<td></td>
<td>Aaron/Pablo</td>
<td>In Progress</td>
<td>Completed PLC routine to control and monitor temperature sensors</td>
</tr>
<tr>
<td>1.5</td>
<td>JT Valves- LVDT monitoring and controls</td>
<td></td>
<td>04/10/20</td>
<td></td>
<td>Pablo</td>
<td>In Progress</td>
<td>Completed readout for JTV 1 to JTV7, and valve WR</td>
</tr>
<tr>
<td>1.6</td>
<td>Cryo - Cooldown Operations logic</td>
<td></td>
<td></td>
<td></td>
<td>Pablo</td>
<td>In Progress</td>
<td></td>
</tr>
<tr>
<td>1.7</td>
<td>NMR unit - PLC communication</td>
<td></td>
<td>04/24/20</td>
<td></td>
<td>Brian</td>
<td>In Progress</td>
<td>Code from SHMS Q1 Hall Probe, will need to update with actual sensor calibration later</td>
</tr>
<tr>
<td>1.8</td>
<td>MPS - PLC communications - ASCII (Research another reliable comm method e.g. Ethernet)</td>
<td></td>
<td></td>
<td></td>
<td>Brian</td>
<td>Not Started</td>
<td>MPS has not been defined yet</td>
</tr>
<tr>
<td>1.9</td>
<td>Magnetic field readout and regulation</td>
<td></td>
<td></td>
<td></td>
<td>Pablo</td>
<td>Not Started</td>
<td>Not required</td>
</tr>
<tr>
<td>1.11</td>
<td>Cooldown Interlocks</td>
<td></td>
<td></td>
<td></td>
<td>Brian</td>
<td>Not Started</td>
<td></td>
</tr>
<tr>
<td>1.12</td>
<td>Power/MPS Interlocks - Fast/controlled ramp downs</td>
<td></td>
<td></td>
<td></td>
<td>Pablo</td>
<td>Not Started</td>
<td></td>
</tr>
<tr>
<td>1.13</td>
<td>High speed voltage tap readout logic to archive</td>
<td></td>
<td>12/15/19</td>
<td></td>
<td>Pablo</td>
<td>In progress</td>
<td>Developing PLC routine to read high speed ADC modules up to 3.3 KHz</td>
</tr>
<tr>
<td>1.14</td>
<td>PLC communication test</td>
<td></td>
<td></td>
<td></td>
<td>Pablo</td>
<td>Not Started</td>
<td></td>
</tr>
<tr>
<td>1.15</td>
<td>Sensors and Instrumentation readout/calibration test</td>
<td>Yes</td>
<td></td>
<td></td>
<td>Brian/Pablo</td>
<td>Not Started</td>
<td></td>
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<tr>
<td>1.16</td>
<td>MPS-PLC Communications Test</td>
<td></td>
<td></td>
<td></td>
<td>Brian</td>
<td>Not Started</td>
<td></td>
</tr>
<tr>
<td>1.17</td>
<td>Test, configure, tune PLC and I/O modules on Solenoid</td>
<td></td>
<td>12/05/19</td>
<td></td>
<td>Pablo</td>
<td>In progress</td>
<td>Testing high speed ADC input modules</td>
</tr>
</tbody>
</table>
Conclusions

- DSG Staff: Pablo (lead), Mary Ann, Aaron, Brian, Marc, and Tyler are developing the PLC controls system for the SoLID magnet to provide precise and safe controls
  - Cooldown operations
  - Energization: power up/down operations
  - Steady state operation