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THE SNS PLC BASED CONTROL SOLUTION FOR STEPPER MOTORS*

D. Williams†, F. Medio‡, Oak Ridge National Laboratory, Oak Ridge, TN, USA

Abstract

The Spallation Neutron Source (SNS) at Oak Ridge National Laboratory has been operating for over 15 years. Many electronic components are now obsolete and require replacement to assure reliability and sustainability. SNS uses stepper motors to control accelerator components throughout the facility, including the cryomodule tuners, beam scrapers, and the primary and secondary stripper foils. The original motor controls were implemented with VME controllers, custom power supplies, and various types of motor drivers. As these components became less reliable and obsolete a new controls solution was needed that could be applied to multiple motion control systems. Fast performance requirements are not crucial for these stepper motors; therefore, the Programmable Logic Control (PLC) technology was selected. The first system replaced was the RING stripper foil control system and plans are underway to replace the beam scrapers. This paper provides an overview of the commercial off-the-shelf (COTS) hardware used for the new stepper motor control at SNS. Details of the design and the challenges of converting a control system during short maintenance periods without disrupting beam operation will be covered in this paper.

INTRODUCTION

The original hardware provided by Brookhaven National Laboratory for the stepper motors in the RING primary and secondary stripper foils was a Versa Module Europe (VME) based system with Pacific Scientific motor drivers, Acopian power supplies, OMS VME58 and VME digital I/O boards. The Experimental Physics and Industrial Control System (EPICS) interface had several parameters that were not well understood, and documentation of their functionality was minimal. The Pacific Scientific motor driver configuration parameters were stored in the hardware and retained by the onboard battery. These batteries were having end of life failures and when power was lost, the parameters had to be reloaded manually. The batteries were soldered onto the circuit boards that had to be disassembled for replacement. All the major components were obsolete and spares on-hand were running short from previous failures. With the increased of risk of downtime running the current system, a new control solution was required.

NEW PLC BASED STEPPER MOTOR CONTROLS DESIGN

Goals for the new design included using commercial off-the-shelf (COTS) hardware from established SNS standards. The SNS standard PLC is Allen-Bradley ControlLogix [1] and the AMCI SD4840E2 stepper motor controller was selected for compatibility with our PLCs. The AMCI SD4840E2 stepper motor controller [2] combines both motor drive and controller in one Ethernet IP module which reduces the cost compared to a separate motor controller in the PLC chassis for each stepper motor. An AMCI ANA2 Ethernet resolver was also used for position readback for the chainsaw signal used to rotate a different foil on the changer. The existing stripper foil field hardware in the RING tunnel and associated field cables would be repurposed for the new design. Connectors were added to these cables to allow rollback to the old system if required during the initial production run of the new PLC system. The Acopian power supplies were replaced with two Sola 24VDC power supplies.

Architecture of the Motor Controls

A Soft IOC replaced the VME IOC and associated hardware to communicate to the PLC for status and issue commands to the foil controls. New streamlined operator screens were developed for commanding stepper motors for the plunge and chainsaw drives. The EPICS engineering screens that allowed an operator to change the dynamics of the motor driver parameters were eliminated to prevent improper control of the motors performance that could potentially damage the foils. These are now embedded in the AMCI driver controller and are not available for an operator to change the stepper motor's performance.

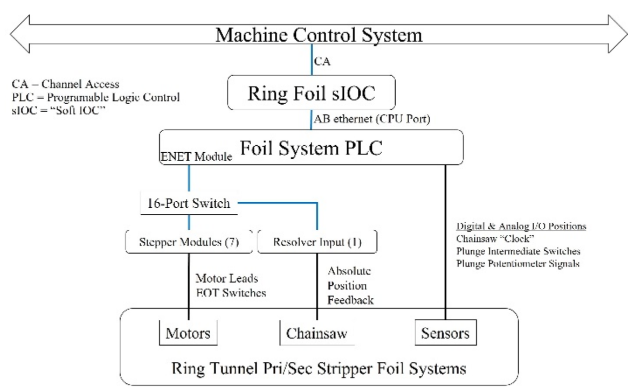

Figure 1: Control system architecture diagram.

The Soft IOC communicates over the machine Ethernet network to the PLC processor's Ethernet port using TCP/IP [3]. A separate PLC Ethernet module is connected to an unmanaged switch that is connected to the stepper motor controllers and the resolver input modules (Fig. 1). These AMCI modules are hardwired to the field devices i.e., step-per motors and resolver. The input signals for the chainsaw limit switches used to indicate which foil is inserted into the beamline are hardwired to the PLC digital input module located in the PLC chassis. A PLC analog input module is used as a potentiometer for the plunge motion of the foil.

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†williamsdc@ornl.gov
‡mediofc@ornl.gov

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All motion control logic for the RING foil changer is in the PLC and can be used as a stand-alone system for control with a PanelView HMI if necessary, during a machine network outage or preliminary testing of the system. EPICS tools are the primary operator interface and are used for normal operations.

Stepper Motor Controller Software

AMCI provides Ethernet configuration software for the stepper controller and for all the motor dynamic parameters that are stored in the module (Fig. 2). This configuration can be saved to a file and kept in the PLC repository AssetCentre. The file can be easily downloaded to a replacement motor driver controller if a failure occurs for quicker recovery time. The programming and configuration over the network are simplified by using the PLC's native software (Studio 5000). No extra software is required, and there is no need to learn another programming language. Additionally, the PLC retains configuration data for each stepper controller. When a controller fails, all that is required is setting the IP address in the replacement controller. Once the new stepper controller is put in place the PLC recognizes and transfers the motor configuration to the controller. AMCI's SD4840E2 Networked Series [4] integrates with Ethernet/IP compatible with Allen-Bradley PLCs. AMCI provides the EDS file for configuring in the I/O tree as well as sample PLC code. This code is dropped into a task in the PLC for each motor that is called by the main routine for execution.

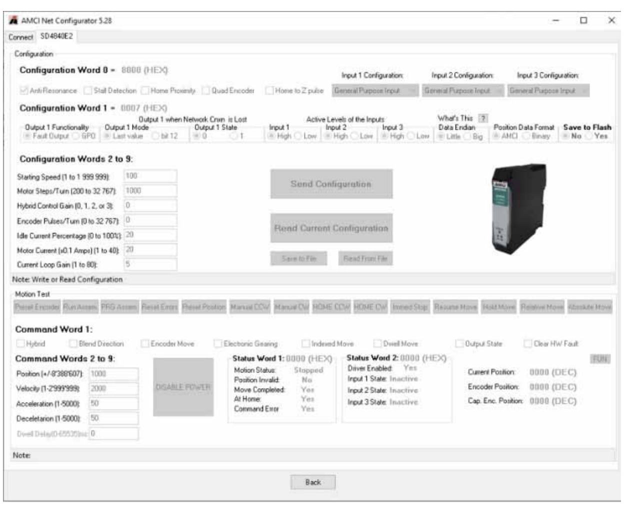

Figure 2: AMC configuration software example.

PREPARATION AND PROTOTYPE

A complete prototype was built on a test stand on wheels for the spare foil changer; the spare is identical to the production changer installed in the RING (Fig. 3). The test stand was fitted with a wiring harness and connectorized to mate with the foil changer connectors. The test stand used a PanelView HMI for local control that matched the functionality of the EPICS control screens. The vacuum chamber was removed on the primary foil changer to observe motor performance of the chainsaw drive and the plunger control. A mock foil was used to measure finite movement of each step change and measured by the Alignment Group. The system was tuned for various speeds and smoothness of travel. The stepper motor controllers were optimised through testing and measurements by the Alignment Group; the results of each axis were for the primary thin foil; index 0.1501 mm/step and plunge 0.0194 mm/step. The prototype control system was only used on the primary thin foil changer because it was the only spare available for testing. The configuration parameters for the plunge were used on the secondary foil changer stepper controller and tested on the production machine in the field.

Figure 3: PLC test stand used on spare primary foil changer.

An EPICS database was created for both foil changers and tested in the lab to complete the vertical testing before installation in the field on the production machine. Operators were consulted in this process to streamline the control screens and to keep some of the features that were most used and familiar to the operators. Screens were developed for the RING scrapers because the new control system included their stepper motors as part of the upgrade project. A total of 7 stepper motor controls were updated with 4 systems on the RING scrapers, 2 for the primary stripper foils, and 1 for the secondary stripper foils controlled by the single PLC system.

This test stand was also used to troubleshoot the production foil changer prior to the PLC upgrade. The old system stopped working due to radiation damage to field cables. To determine if the damage was internal wiring on the foil changer or long field cables, the test system was rolled into the tunnel and connected directly to the changer. Once it was established all control was working while connected directly to the changer, focus was shifted to field wiring

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and quickly resolved. The use of the prototype on wheels in the tunnel reduced downtime significantly.

CONVERTING THE STEPPER CONTROLS IN A SHORT MAINTENANCE PERIOD

A typical SNS maintenance period is 6 to 8 weeks to complete upgrades before operation starts to deliver the proton beam to the target. To complete the upgrade of the stripper foil and scrapper motor controls window in our designated maintenance period, we required two separate outages. The first outage was utilised to place connectors on the field cables to allow the system to be connected to the old VME based system and to the new PLC based system. The PLC based system was not installed at this time because other hardware was rearranged in the control rack to make room for the new system. The length of the outage did not allow time to fully convert the system. Installing connectors on the field cables allows for quick rollback to the old system (Fig. 4). If any unforeseen issues arise with the PLC and new motor controllers during operations, the new EPICS database would be turned off and the old database turned on, the field cables would be connected to the old hardware. This rollback was designed to only take a few minutes to reduce downtime.

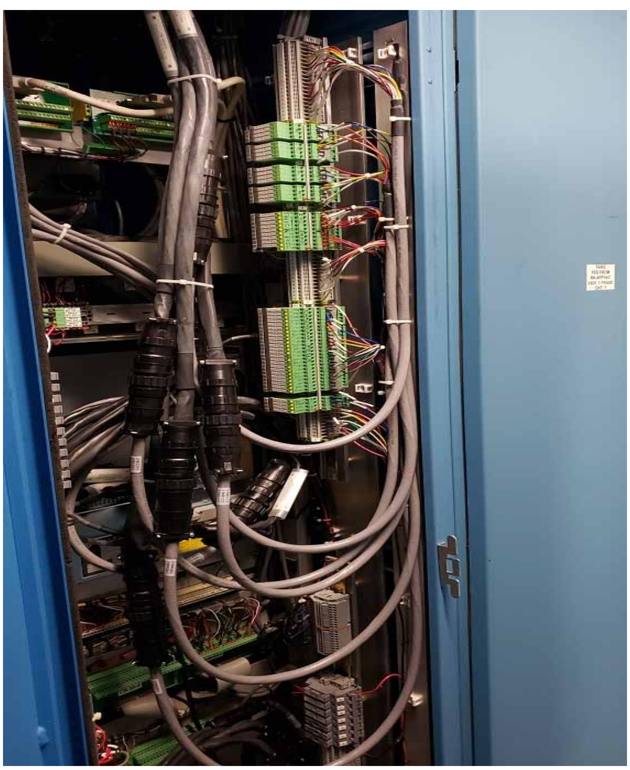

Figure 4: Wiring harness on field cables to PLC or VME based systems to allow rollback.

The second outage was used to install the PLC, motor controller/drivers, and power supply hardware. The new EPICS database was loaded on a soft IOC and the system was commissioned with field hardware. The old system was powered off and left in place to allow rollback. Proper operation of the primary/secondary stripper foils was verified by operations before beam production. The RING scrapers were verified during this time as well. More time was allowed to test the PLC system using the spare foil changer by splitting the installation and commissioning in two separate outages. This also allowed operators to make final changes to the EPICS screens they would be using to operate the foil changer.

CONCLUSION

The PLC based motor control system upgrade using commercial off-the-shelf (COTS) hardware eliminated obsolescence issues with the VME based system and old motor drivers. Streamlining the operator's interface to remove drive configuration parameters, that were not well understood, reduced the possibility of an error causing foil damage. The upgrade was a success with improved performance of motion on the foil changer. To date, no control issues that required rollback to the old system have occurred. Having the confidence of one year of operation without any issues, ensures a path forward to deploying this design to other stepper motor control systems throughout the facility. Recently, this design was used to implement controls for the new gamma blocker system in the RING injection dump section of the accelerator. Plans to upgrade the high energy beam transport (HEBT) scrappers to a PLC based system will take place in the 2023-24 long outage.

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