STEPPER MOTOR CONTROL, PLC VS VME *

Herb Strong, Pam Gurd, Spallation Neutron Source (SNS), Oak Ridge National Laboratory (ORNL), Oak Ridge, TN 37831, USA

Abstract

Traditionally, EPICS-based accelerator control systems have used VME-based motion control modules to interface with stepper motors. For systems that include some Programmable Logic Controllers (PLC), there is an option for using PLC-based stepper motor interface modules. As with all control system choices, there are trade-offs. This paper will delineate some of the pros and cons of both methods of interfacing with stepper motors.

VME-BASED STEPPER MOTOR USAGE

Stepper motors are used at the Spallation Neutron Source to control beam-insertable devices such as scrapers, diagnostic devices and stripper foils. They are used in the superconducting portion of the linac to tune the frequency of the cavities.

Cryomodule Cavity Tuner Controls

The cavity tuner controls were developed by controls personnel at the Los Alamos National Laboratory. The stepper motors for the superconducting cavities are located inside the cryomodules and the tuning mechanism is connected to the cavities. One of the requirements for components located inside the cryomodule is to minimize the amount of heat produced. Also, signals from the cryogenic temperature sensors (silicon diodes) are sensitive to electrical noise. The controls for the superconducting cavity tuners were implemented to reduce the amount of heat and noise produced by the stepper motors.

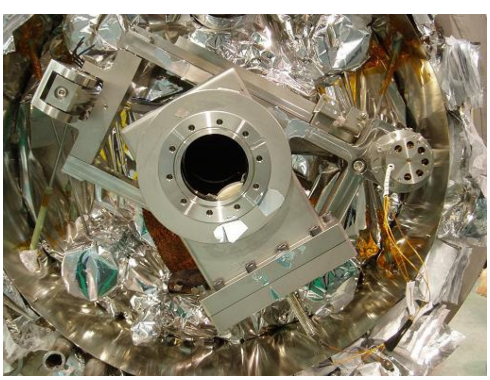

Figure 1: Superconducting cavity tuner.

The stepper motor control board chosen was the Pro-Dex Inc. [1] (Oregon Micro Systems) VME58 8 channel stepper motor controller. Phytron [2] SINCOS stepper motor drive modules were chosen to reduce the electrical noise. They have a linear power stage. Two custom interface boards connect the Pro-Dex module to the motor drives and stepper motors. One board mounts in the back of the VME chassis and is used to interface the Pro-Dex board to a drive interface chassis. The drive interface chassis routes the Pro-Dex motion control signals to the motor drives. It also converts the 24 volts direct current (vdc) clockwise and counterclockwise limit switch signals to Transistor Transistor Logic (TTL) levels.

During start-up of the tuner control systems, numerous problems were encountered with the custom interface modules. Most were due to field wiring errors that caused failures of the TTL-integrated circuits. Several spare interface modules were fabricated to assure we could keep the accelerator in operation. During fabrication of the spare modules, we learned that several of the components were obsolete. After initial start-up wiring problems were corrected, the failure rate has been essentially zero and none of the spare modules have been used.

Foil and Scraper Controls

The controls for the insertable foils and scrapers were developed by Brookhaven National Laboratory. The scraper devices are designed to be precisely positioned into the edge of the beam to remove electrons from the particles that are outside the desired beam profile. These scraped particles are then routed to a collimator or dump. A single axis of motion is provided. A feedback potentiometer is used to accurately determine the position of the edge of the foil in relation to the centroid of the desired beam line. Due to the mechanical design of the 4-ring primary scraper, a brake was required to hold the mechanism in the desired position.

Figure 2: Primary stripper foil mechanism.

The primary stripper foil is used to strip the SNS accelerator H^- beam to produce H^+ particles that are injected into the storage ring. The mechanism that

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positions the stripper foils looks similar to a chain saw. Foils are attached to brackets that are connected to the chain. A stepper motor drives the chain in both directions. Limit switches provide indication that a stripper foil is near a desired location. The second stepper motor is used to drive the entire chain-drive slide mechanism closer to or further from the beam. A feedback potentiometer provides accurate feedback of the slide position. A video camera has a direct view of the primary stripper foil area. Once the selected foil is close to the desired position, the image from the video camera is used to precisely position the foil. The chain-drive moves the foil in the vertical and horizontal directions and the slide-drive moves the foil in the horizontal direction only.

Figure 3: Primary stripper foils and chain.

The stepper motor control board chosen was the Pro-Dex VME58 8-channel stepper motor controller. Pacific Scientific stepper motor drive modules were used to power the motors. A custom module designed by Brookhaven is used to interface six of the eight channels of the Pro-Dex module to the drives and limit switches. Thus, two of the Pro-Dex channels are not used. The auxiliary outputs provided on the Pro-Dex module were used to control the brake. A VMIC module is used to monitor the primary stripper foil position switches. External relays are used to convert the 24 vdc signal from the limit and position switches to TTL levels.

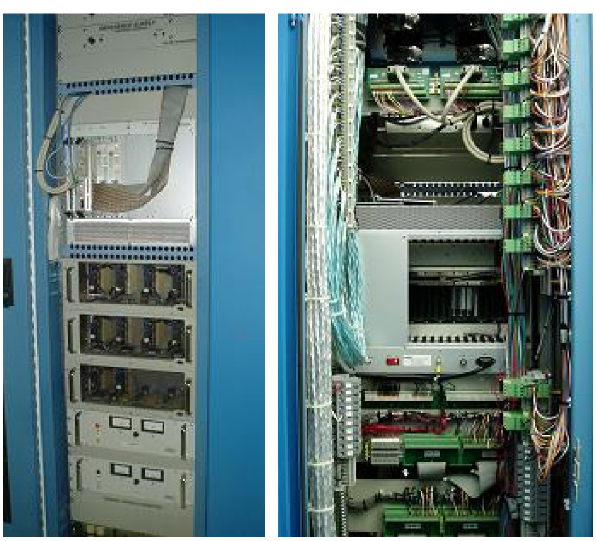

Figure 4a and 4b: Front and rear of VME-based stepper motor control cabinet.

During start-up of the foil and scraper control systems, no problems were encountered with the custom interface modules. Several of the Pacific Scientific modules failed, probably due to numerous field wiring errors. After initial start-up wiring problems were corrected, only one drive module failed, quite likely because of the initial wiring errors.

PLC-BASED STEPPER MOTOR CONTROLS

A cryomodule test facility was constructed at the SNS site. At the time construction on this facility started, we were still concerned with the problems encountered with the VME-based stepper motor controls. It was decided to pursue a more commercially-based stepper motor control system to use for controlling the cryomodule cavity tuners. Since we used numerous standard Allen-Bradley Programmable Logic Controllers (PLCs), we picked a stepper motor controller that would reside in the PLC chassis. The Advanced Micro Controls Inc. [3] (AMCI) 3204 4-channel stepper motor controller was chosen.

Hardware Interface

The AMCI module step and direction signals are TTL compatible and thus interface directly with the Phytron stepper motor drives. The switch inputs for the clockwise, counterclockwise, and home limit switches are designed for 24 vdc signals and were connected directly to the wiring from the switches. This greatly reduces the size and complexity of the interface modules.

Figure 5: VME interface module (large green board) and PLC interface module (small yellow board).

As noted earlier, one of the requirements for the cavity tuners is to minimize the amount of heat dissipated in the cryomodule. The AMCI module has no auxiliary output that can be used to deactivate the drive current. A separate PLC TTL output module and interface board was required to provide an open collector signal required by the Phytron stepper motor drive to turn off the drive current.

Figure 6a and 6b: Front and rear of PLC-based stepper motor control cabinet.

Software Interface

While a mature EPICS device driver is available for the Pro-Dex VME-58 module, a PLC-based device driver had to be developed for the AMIC module. The minimal PLC programming examples provided with the module were barely enough to make the module operate and much less than the detail required to start the development of an interface.

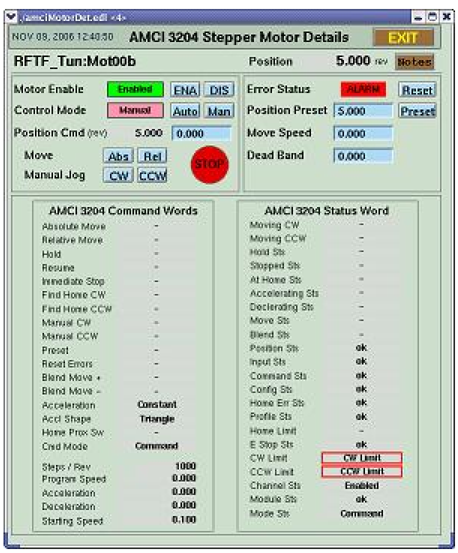

Figure 7: EPICS stepper motor detail screen.

The AMCI module itself has a good set of control functions and provides sufficient status and feed-back information. The most difficult part of the interface involves the manner in which the module reacts to the activation of either of the end-of-travel limit switches. It is designed with the assumption that a limit switch is outside the normal range of travel. Any time a limit switch is activated the module stops motion and reports an error condition. While a limit switch is active, the module ignores absolute and relative move commands. It will respond to reset and preset commands. The only way to move the mechanics from the limit switch is to first reset the error status and then issue the appropriate jog command to the motor controller. If the clockwise limit switch is active, a jog-clockwise command will result in another error. For some applications such as the cryomodule cavity tuners, where it is never desirable to drive the tuner to the limit, this response is acceptable. If the tuner ever reaches a limit switch, some control system problem has likely occurred.

Valve Control

Early this year, another opportunity arose to use the PLC and AMCI stepper motor controls. The controls for the ORNL High Flux Isotope Reactor Cold Source included several control valves actuated by stepper motors. The original PLC software developed for control of the valves proved inadequate. The PLC device driver written for cryomodule tuner control was used as a starting point for a device driver for the Cold Source valves. The major difference for this application was that when the valve was fully closed, the closed limit switch was activated. The device driver was modified to automatically recover from closure of the switch. When the valve is commanded fully closed and the switch is activated, error conditions are reset and the current valve position is preset to 0%. Since the limit switch is still active, the only way to move the valve away from the limit is to use the jog command. The device driver automatically jogs the valve until it clears the limit switch and then issues an absolute-move command to move the valve to the desired position.

SUMMARY: PLC AND VME

Both VME-based and PLC-based stepper motor controls have been successfully developed and implemented. Both have proved to be reliable and easy to maintain.

PLC-based controls have the following advantages:

- Fewer custom interface modules
- Less cabinet wiring
- Directly connects to 24 vdc limit switches
- Easier to integrate motion control and interlock logic
- Safer limit switch response

VME-based controls have the following advantages:

- More complete device driver
- Less custom device driver logic
- Higher density per module (8 channel vs. 4)
- Faster EPICS updates
- Auxiliary outputs included on VME module

Technically, there is no clear reason to choose VME- over PLC-based stepper motor controls. The most likely reason to choose one over the other is the need and availability of a VME or PLC chassis used for other portions of the control system.

REFERENCES

[1] Pro-Dex Inc., (Oregon Micro Systems), www.omsmotion.com
[2] Phytron, www.phytron.com
[3] AMCI, Advanced Micro Controls Inc. www.amci.com