THE SNS FRONT END CONTROL SYSTEM UPGRADE*

W. DeVan, X. Geng, A. Justice, J. Tang, D. Williams, ORNL, Oak Ridge, TN 37831, U.S.A.

Abstract

The Spallation Neutron Source (SNS) Front End (FE) is comprised of a 35 mA volume H^- source, a multi-element electrostatic Low-Energy Beam Transport (LEBT) section including chopping and steering, a 402.5 MHz Radio Frequency Quadrupole (RFQ) with low output emittance, and a 2.5MeV Medium-Energy Beam Transport (MEBT) section that also includes chopping. The original control system was designed and built by Lawrence Berkeley National Laboratory (LBNL) during 2000-2002 and commissioned at SNS in 2003. The FE control system design occurred early in the project and preceded finalization of SNS control system standards. The system was implemented based on Allen-Bradley[1] VMEBus Remote I/O Scanners and PLC5s™ with Flex I/O interfaced via Remote I/O communication. The FE control system is now being upgraded to comply with the SNS standard PLC implementation and to improve reliability and maintainability. Details on the upgrade will be presented in this paper.

FRONT END CONTROLS

The Spallation Neutron Source Front End is comprised of a 35 mA volume H^- source, a multi-element electrostatic LEBT section (which includes chopping and steering), a 402.5 MHz RFQ with low output emittance, and a 2.5MeV MEBT section that also includes chopping. The original control system was designed and built by LBNL during 2000-2002 and commissioned at SNS in 2003. The FE control system provides operational controls and interlocking of high-voltage power supplies, vacuum systems, magnets and magnet power supplies, cooling water systems, choppers, and an equipment protection system.

INITIAL IMPLEMENTATION

The FE control system design occurred early in the project and preceded finalization of SNS control system standards. Fortunately, standardization had progressed far enough that the Experimental Physics and Industrial Control System (EPICS) [3] had been picked as the SNS distributed control system standard. Consequently FE distributed control system functionality was implemented in EPICS and conformed to SNS standards from the beginning. However, local controller hardware/software standards had not yet been finalized. Much of the local controls were implemented based on Allen-Bradley (A-B) VMEBus Remote I/O Scanners, PLC5 processors, and Flex I/O, all interfaced via A-B Remote I/O communication. At the time, this same architecture was in use by Advanced Photon Source (APS) and so enabled LBNL to use proven EPICS interface software. Vacuum system controls, cooling water controls, and equipment protection were implemented using the A-B hardware.

Another feature of the FE Control system is the use of

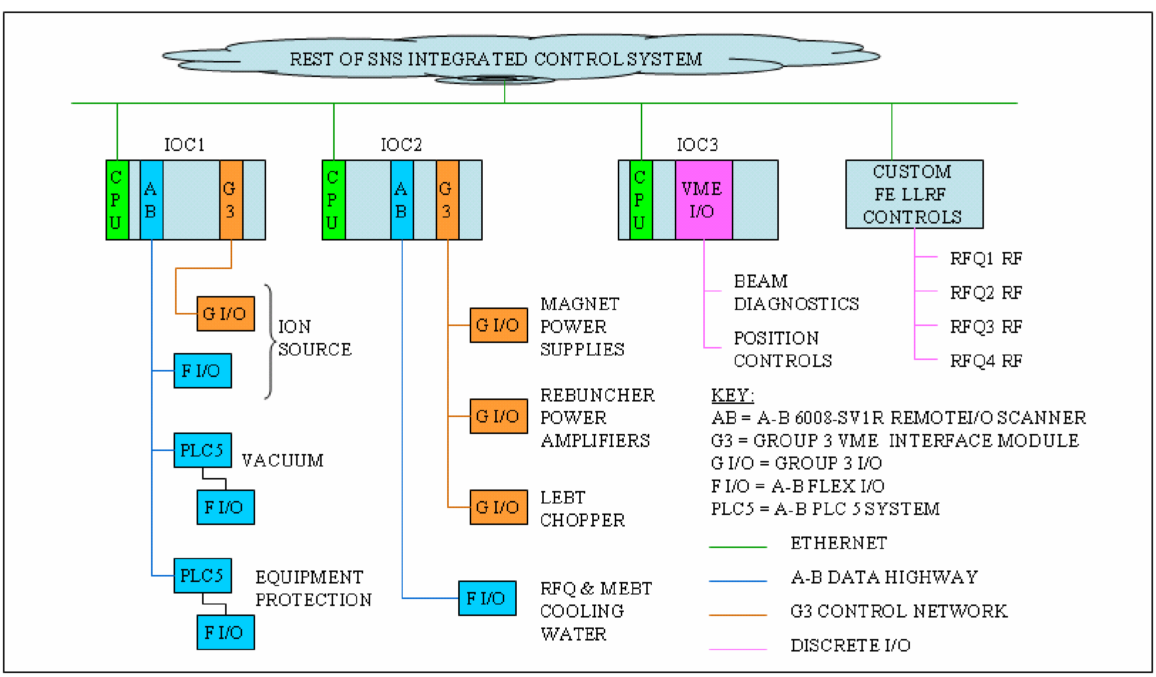

Figure 1 –SNS Front End Control System Architecture as Initially Commissioned

* ORNL/SNS is managed by UT-Battelle, LLC, for the U.S. Department of Energy under contract DE-AC05-00OR22725.

Group3 Technology Ltd. [2] distributed I/O systems. Communications between distributed I/O modules is via a fiber optic ring. This I/O architecture enabled installation of I/O modules on high-voltage stacks alongside high-voltage power supplies. Group3 I/O is used to interface with high-voltage power supplies, magnet power supplies, and the MEBT RF power amplifiers.

Most of the FE control logic was carried out within the EPICS I/O Controllers (IOCs), with the PLCs serving primarily as I/O handlers. The EPICS controls were concentrated into three VME-based IOCs. Figure 1 shows the initial Front End control system architecture.

CONTROL SYSTEM UPGRADES

The FE control system (along with the FE itself) was commissioned at SNS in 2003 and has served the facility well. Over time the control system has been incrementally upgraded to improve standardization, availability, and maintainability. Figure 2 shows the architecture as it stands today.

Increased Controls Distribution

One of the first actions taken was to further modularize control functions for improved maintainablility. Vacuum and power supply controls were moved to dedicated IOCs. This was primarily a hardware expense and required little engineering effort.

Standardization of PLC Hardware

As stated earlier, the FE PLC controls were originally based on A-B PLC-5s and A-B Remote I/O communications. The FE IOCs interfaced with the PLC5s and Flex I/O via A-B 6008-SV1R VME modules, which are no longer sold or supported. SNS ultimately standardized on Allen-Bradley ControlLogix™ PLCs with an "EtherIP" interface to IOCs. Another difference between the Front End and the rest of SNS was that A-B ControlNet was selected as the SNS PLC-to-remote-I/O communications standard. This left the FE control system as the only place where PLC5s and Remote I/O communications were being used. In the interest of standardization, the vacuum, cooling water, and equipment-protection PLC5s were replaced with ControlLogix PLCs, ControlNet remote I/O communications, and an EtherIP interface to FE IOCs.

Allen-Bradley provides a software tool for translating PLC5 programs into ControlLogix programs. Some minor clean-up was required after the translation, but the tool did save some development time.

As part of this transition, a number of interlocks formerly implemented in EPICS IOCs were moved to PLC logic. The bulk of the vacuum system sequencing logic still remains in the IOC, but plans are to ultimately move this functionality to the vacuum PLC.

A side benefit of the upgrade has been an improvement in response time and reliability in the execution of interlocks. Some interlocks originally had long paths between the sensor and the final control element. For example, the RFQ vacuum interlock of RF took the following path:

- From vacuum PLC to vacuum IOC (via A-B Remote I/O communications), then

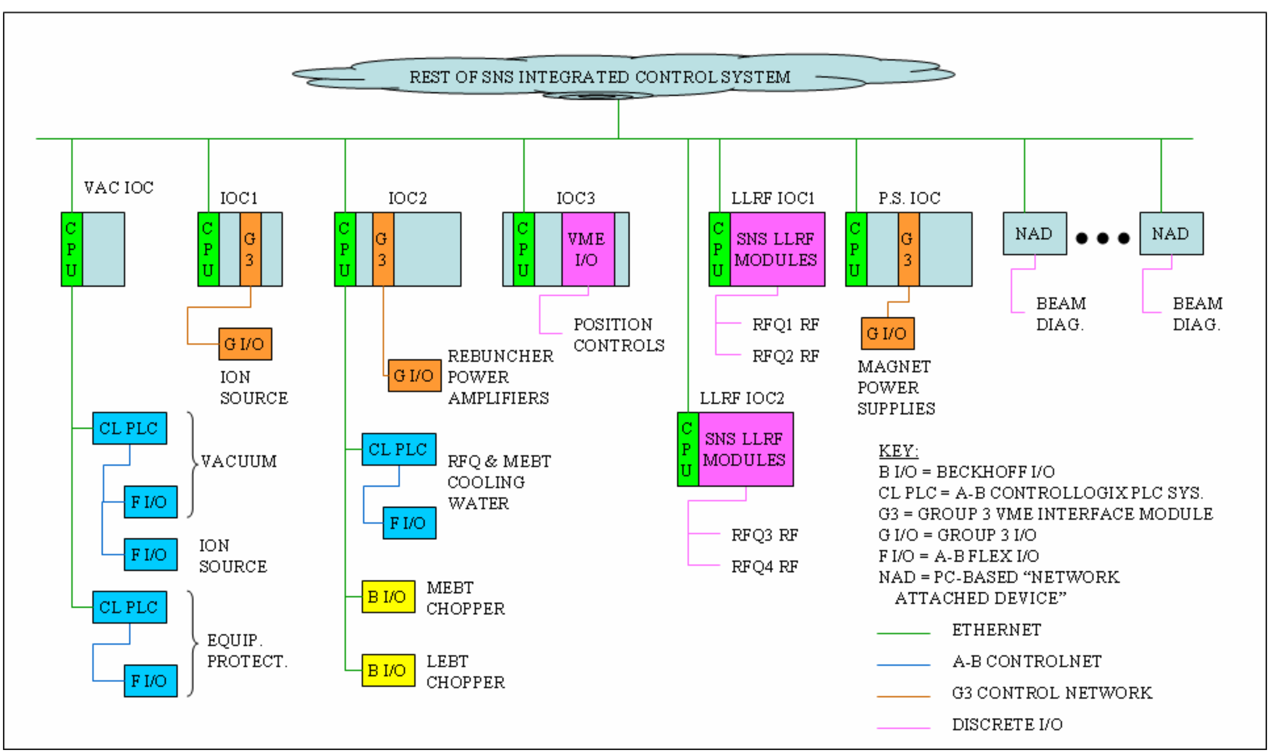

Figure 2 – Present Front End Control System Architecture

- From vacuum IOC to cooling water IOC (via Ethernet), then
- From cooling water IOC to remote I/O (via A-B Remote I/O communications).

The biggest time delay was attributed to I/O scanning via A-B Remote I/O communications. (A-B Remote I/O is an aged, proprietary network that typically runs at 57.6 kbit/sec.). It was estimated that the delay time from a vacuum excursion to shut-off of RF was over 1 sec. The path of this example interlock is now:

- Vacuum PLC to cooling water PLC (via A-B ControlNet), then
- Cooling water PLC to remote I/O (via A-B ControlNet).

We estimate the time delay now to be on the order of 10 msec.

Flowmeter Replacement

Cooling water flows in the many RFQ and MEBT cooling water lines were originally monitored via paddlewheel-style flowmeters. As these units aged they became less reliable and tended to have intermittent problems. Since RF is interlocked by these flows, this caused significant downtime. The paddlewheel-style flowmeters were recently replaced with ultrasonic flowmeters and so far these are performing well.

Other SNS Standards Implemented

Implementation of FE Low-Level RF (LLRF) controls occurred before the standard complement of SNS VXI-based LLRF control modules was developed. This left LBNL having to develop their own custom LLRF controls. These one-of-a-kind LLRF controls were ultimately replaced with two SNS-standard LLRF IOCs.

Similarly, LBNL developed several beam diagnostics systems before the SNS standard beam diagnostics were ready. These have since been replaced with the SNS standards.

RFQ Resonance Control

At the time this paper was written, automatic RFQ resonance control was in the process of being implemented. Originally the RFQ resonant frequency was controlled by setting the supply temperature of two chilled water circuits. (One chilled water circuit cools the RFQ vanes; the other the RFQ walls). The desired resonant frequency was obtained by manually setting the temperature setpoints of each PID controller in the two chillers. The setpoints were adjusted by operators until the desired resonant frequency is achieved. This worked acceptably well since once the proper temperatures were established, the resonant frequency remained stable for long periods.

The new automatic RFQ resonance control strategy is based on cascaded control loops. The master loop will execute PID control based on resonance error, and the slave loops will consist of the PID temperature controllers in the chillers.

Plans for the Future

Other standardization efforts being considered include the following:

The SNS control system uses a standard magnet power supply interface consisting of a VME-based “power supply controller” (PSC) module communicating with up to six “power supply interface” (PSI) units (one PSI per power supply). (These units were developed by Brookhaven National Laboratory for SNS). Long-term we would like to replace the existing Group3 power supply interface with the standard SNS PSC/PSI interface.

The standard SNS RF transmitter uses an A-B ControlLogix PLC system for local controls and interlocking. The Front End Buncher power amplifiers are currently interfaced with via Group3 remote I/O. Long-term we hope to replace this interface with a more-standard and more-flexible PLC system.

SUMMARY

The FE control system has been successfully upgraded to match SNS standards, replace obsolete components, increase maintainability, and improve performance. This was all accomplished within scheduled accelerator maintenance periods.

REFERENCES

[1] Rockwell Automation (Allen-Bradley product line), http://www.ab.com/
[2] Group3 Technology Ltd., http://www.group3technology.com/
[3] EPICS home page: http://www.aps.anl.gov/epics