STATUS OF THE NSCL ACCELERATOR AND BEAM TRANSPORT ELECTRONIC SYSTEMS

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Introduction

The primary focus of the Electronics Department efforts this year has been facility upgrades including the Coupled Cyclotron Project (CCP) and general reliability improvement. The first half of the year from January to July included supporting the operation of the experimental program, fabrication of CCP components, and CCP construction as allowed. Previous to the CCP shutdown, to the extent that operations could be reasonably sustained, areas (such as the A1900 Power Supply Area, the K1200 RF Balcony, the K500 RF Balcony) were cleared of equipment or rearranged and prepared for the upcoming upgrade. The focus shifted completely to the CCP and reliability upgrades after the shutdown began in July. The first substantial task was to remove the existing systems. Following demolition, the construction of the CCP supporting infrastructure that could not be prepared in advance began. This report shall focus on the elements of the facility upgrade rather than on the last months of operations. With the exception of the K1200 cyclotron, the entire facility outside of the experimental vaults has been removed and reorganized, upgraded or replaced.

General Controls and Instrumentation

The NSCL has a reasonably large control system consisting of approximately 20 VME crates loaded predominantly with analog or serial I/O and 5 large PLCs, each of them supporting many I/O drops and analog or digital I/O as needed. In addition, custom instrumentation and servo systems are applied when commercial components are either not appropriate to the task or not economical. This section will give a brief discussion of each system so that common elements in the system are not repeatedly described in the ensuing sections of this paper.

Programmable Logic Controllers (Modicon PLC’s)

Control signals are increasingly routed through PLC’s at the NSCL. The PLC’s are being reorganized into a functional arrangement versus a topological arrangement and upgraded to the new Modicon Quantum line. Most of the existing 800 series PLC I/O were retained or reused. New I/O drops use Quantum I/O. The newly arranged PLCs will include: 1) the cryogenic plant PLC, 2) the cryogenic load PLC - cryostats and distribution system, 3) the ECR PLC - ECRs and injection lines, 4) the accelerator PLC - cyclotrons and coupling line, and 5) the beam transport PLC - beamlines and vaults. Because these functions are reasonably isolated, communication between PLCs is minimized and predominantly done directly through relay-isolated I/O when needed. Because accurate (16 bit) and reasonably dense (32 channel) analog input modules have recently become available, many more analog signals are being brought into the PLCs directly, whereas, previously these signals would be initially conditioned through comparator cards or brought into the VME system analog I/O. In the near future, we expect similar analog output modules to become available thereby extending the trend of direct PLC I/O to this I/O type as well. Once acceptable analog output cards for the PLC become available, we expect to begin shifting the power supply analog controls from the VME system to the PLC system directly. This would likely be done with the funds normally needed to support the VME analog I/O by augmenting our VME spare parts with parts removed from service rather then through new purchases. Eventually, this process would lead to reduced maintenance costs while simultaneously extending our functionality and significantly simplifying the overall control system. It is believed that the vast majority of device level control can be done through off-the-shelf industrial controls in the near future (5 years) greatly reducing the need for custom systems and the associated complex implementation and maintenance expenses. The upgrade of the PLC system is well underway and should be completed on schedule during the first half of next year.

VME (EPICS Systems)

The NSCL has a reasonably large installed base of VME based computers and associated I/O (~300k). To extend the life of this system, the systems are being upgraded with new computer cards and converted to the EPICS control software. This upgrade is well underway and should be completed next year on schedule. This EPICS upgrade is being covered in detail in another paper in this annual report so nothing further will be said here.

Beam Current Meters (BCM)

The NSCL requires BCMs that span a large signal range, are reasonably accurate, have reasonably fast response rates, are affordable, and are easily coupled to large distributed control systems. The combination of these requirements leads us to designing and building our own electronics. The current design features two galvanically isolated independent channels that span 16 ranges from 30 pA through 1 mA full scale. The unit connects to the control system through an RS-485 electrical connection and a custom designed protocol. Thirty-two of these 2-channel units have been produced and are used throughout the NSCL in applications ranging from beamline Faraday cups to moving beam probes in the cyclotrons that are used to plot beam current versus cyclotron radius. These meters have been in use for the past 2 years and the units required for the CCP upgrade are fabricated. The units for the cyclotrons are installed and the beamline units will be installed as the beamline is installed next year.

Motor Servos

The NSCL uses 3 types of servos for this application: 1) A so-called “Bang-Bang Servo” (BBS) that uses synchronous ac motors, 2) a DC Motor Servo (DCS), and 3) a Stepper Motor Servo (SMS). The basic design for each of these may be packaged in different ways based on the application. For example, the cyclotron extraction drives require many BBS drives in a dense packed location so they are coupled to the control system with direct analog and digital I/O, whereas, other BBS drives are sparsely located and designed to be interfaced to the controls system via an RS-485 serial link. This idea extends to the other drives as well. In general, the type of drive applied is based on the necessary positioning accuracy required, although some overlap between the three types exists. The highest accuracy is achieved with SMS drives, followed by DCS drives, and finally BBS drives. Of the three types, DC drives are also the only drives suitable for application where continuous holding or correcting torque is required, since the other types are disengaged when the desired position is achieved. These units are fabricated and the installation is complete on the cyclotrons. Installation of these units along the beamlines should be completed next year as the beamlines are installed.

Cryomonitors

The NSCL has developed new cryomonitors for the facility. These cryomonitors will be used not only for the new magnets associated with the CCP, but will replace all existing cryomonitors. This was needed to support the new arrangement of PLCs into functional versus topological arrangements as well as to replace aging equipment for reliability reasons. The previous generation of cryomonitors had limited expandability, were labor intensive to construct and repair, and required local interlock calibration via many resistive pots to set comparator limits. This last point leaves a great deal of uncertainty with proper calibrations being maintained. The new design uses a system of boards that plug together directly to eliminate most of the internal wiring and utilizes industry-standard off-the-shelf “5B” signal conditioning modules for most functions. These units can be easily expanded by plugging in additional 5B modules into available slots to accommodate a large number of, and a wide range of, signals and sensors. The new cryomonitors send conditioned analog signals to two PLCs directly and do not include internal adjustments. Incidentally, the direct analog interface facilitates any future process control that may be needed. Transition lead drops are sent to the PLC that controls the state of the power supplies while other information associated with maintaining the cryogens (He level, pressure, etc.) are sent to the cryogenic load PLC. The necessary comparator functions, if any, are then performed in the appropriate PLC. The PLCs can signal each other via discrete I/O in the cryomonitor to handle interlock conditions that bridge the functional domains of the controllers. We have found this method to be more reliable than the previous use of proprietary digital networks for this purpose. Final fabrication and installation of these units should be completed on schedule the first half of next year.

New Cryoplant Facility

A new 1500 Watt cryoplant began construction this year. The plant is arranged into multiple functional units (1500 HP compressors, refrigerators, etc.). The instrumentation and actuators are wired into one or more interface boxes mounted on each unit. A central control room in the plant contains a control console, equipment racks, and one of five PLC I/O cabinets used to control the plant. The control console is PC based and contains three PC’s and six monitors. The PC’s are used as operator interfaces and perform no control or interlock functions. The PCs include software such as the EPICS MMI screens, Labview apps, custom NSCL MMI software - such as the PC Panelmate application, chart recorders, DDE interface to other applications, etc. The equipment racks contain contamination monitoring equipment, the cryoplant PLC, the cryoload PLC, as well as room for expansion. The cryoplant control and interlock functions are performed exclusively by the cryoplant PLC (a Modicon Quantum PLC described previously) coupled to five remote I/O cabinets. Control functions performed include interlock control, sequence control, and approximately 40 PID process control loops. The cryoplant PLC I/O cabinets contain the PLC I/O modules, some cryogenic instrumentation, and some DIN rail mounted signal conditioners. The PLC I/O drops contained within the PLC I/O cabinets are connected to the PLC via two redundant serial links over coaxial cables that are daisy chained from cabinet to cabinet. All of the approximately 500 cryoplant analog and digital I/O points are serviced in this manner. In addition to the cryoplant PLC, the cryoload PLC is also housed in the cryoplant control room. The cryoload PLC connects to multiple I/O cabinets sparsely distributed within the NSCL in the same fashion as the cryoplant PLC. It exclusively provides for the control and monitoring of the cryogens in all of the superconducting apparatus. This project should be completed in the first half of next year on schedule.

ECRs and Injection Lines

The ECRs and their controls and power supplies as well as the injection lines (for both the K500 and K1200 cyclotrons) controls and power supplies were totally rearranged and upgraded as needed to facilitate room for the cyclotron coupling line. An extension was made to the K1200 RF balcony to accommodate the ECR power supplies and the cyclotron coupling line power supplies. All of these power supplies and controls are now operating from that location. A problem with an EPICS VME crate, in close proximity to the ECRs, resulting from localized EMI from ECR high voltage breakdown is being resolved. A plan to remove the effected EPICS crate and to transfer the I/O to more robust PLC I/O is being implemented since attempts at shielding, signal conditioning, and power conditioning have failed. It is hoped this will resolve the problem. With the exception of the minor problem mentioned, this project was completed on schedule and is now operational.

Cyclotrons

To review, the K500 cyclotron rf system and all of the electronics have been almost entirely replaced, while the K1200 is in the midst of a minor control revision. The K500 cyclotron has been recommisioned, and the K1200 will be next year.

RF Systems

The entire K500 rf system has been replaced with the exception of the dees, liners, and some of the stem outer conductors. The dees were stiffened, and the liner valley sections totally redesigned and replaced. The new K500 transmitters are predominantly copies of the K1200 transmitters and as a result can share the spare parts stock. The K1200 rf is in the midst of a control electronics upgrade. The grid and screen power supplies for both cyclotrons are aging Kepco vacuum tube based units and are scheduled to be replaced next year. The K500 final anode power supply that delivers 20 kV at up to 7 ADC to each of the three rf amplifier final anodes has been replaced by a unit designed and built at the NSCL. The K500 rf system is operational and there are no significant problems to report. As mentioned, the K1200 rf is due to be brought back online in the first half of next year.

Power Supplies

The K500 main magnet power supply has been totally rebuilt and repackaged. The new power supply and associated new regulation software are routinely achieving 2.5 ppm regulation. The regulation software is somewhat complex and may be classified as a Multiple-Input-Multiple-Output (MIMO) system using non-linear and adaptive techniques to achieve the regulation observed. The trim coil power supplies were updated as well with new controllers and the unreliable mechanical reversing switches were replaced with solid-state ones. These systems are in routine operation and have been trouble free. The K1200 cyclotron has no power supply upgrades or changes scheduled and no major problems to report.

Controls

All of the K500 control wiring, servo drives and instrumentation were replaced, starting with a blank slate. The K1200 is in the midst of minor rf control upgrades. All of this is either complete or on schedule.

Cyclotron Coupling Line

The coupling line is on schedule and due to be complete the first half of next year. A small section has already been operated for K500 Cyclotron commissioning.

A1900 Fragment Separator

The A1900 is scheduled for installation the first half of next year. The electronics infrastructure consisting of thirty-two 19" racks and the associated cable trays, electrical utilities, and LCW plumbing is currently being installed. The majority of the power supplies are on order and the controls are being designed.

Transfer Hall (Beamline Switchyard)

The transfer hall beamline equipment has been totally removed and is scheduled for reinstallation the second half of next year. The electronics, with the exception of the cryomonitors, will be mostly reused from the previous installation, although it will have been serviced, rearranged, and reinstalled.

Experimental Vaults

In general, the experimental equipment in the vaults was left untouched by the changes to the accelerator and beamline controls. Each vault contains two to four magnets packaged in one or two cryostats on the final leg of the beamline feeding the experimental apparatus. These final magnets are treated as extensions of the transfer hall and need to be upgraded with new cryomonitors and reattached to the power supplies and controls. This work is scheduled to be done along with the transfer hall work the second half of next year.

The S800 vault must be upgraded with the new cryomonitors. These cryomonitors will be fabricated the first half of next year and installed either late next year or the beginning of the following year as the schedule permits.

A major upgrade and expansion of the N4 vault is being planned. Although the construction will not begin until late next year, the cryomonitors will be fabricated along with the cyomonitors for the S800 the first half of next year.

Conclusion

As mentioned in the introduction, the NSCL began a major upgrade this year that affected the entire accelerating chain and beamline switchyard (transfer hall). The electronics portion of the work to date is either on time and budget or ahead of schedule. We envision no significant problems to finishing this work on budget and on schedule.