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NSLS-II BEAMLINE EQUIPMENT PROTECTION SYSTEM

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Abstract

The National Synchrotron Light Source II (NSLS-II) beamline Equipment Protection System (EPS) delivers a general solution for dealing with various beamline components and requirements. All IOs are monitored and controlled by Allen Bradley PLC. EPICS application and CSS panels provide high level monitoring and control.

INTRODUCTION

NSLS-II is a state-of-the-art 3 Gev electron storage ring. The facility is designed to accommodate approximately 60 to 70 beamlines when fully built out. Currently around twenty beamlines are in operation and six are under development.

The primary purpose of the beamline Equipment Protection System (EPS) is to protect the individual beamline components against x-ray damage, loss of vacuum, loss of coolant flow (water and liquid nitrogen), and elevated temperatures.

NSLS-II BEAMLINE EPS DEVICES

NSLS-II beamline EPS monitors and interlocks the devices in the front end and the beamline. These devices include photon shutters, masks, slits, vacuum gauges, vacuum pumps, vacuum isolation valves, temperature sensors, water flow sensors, leak detectors, cryocooler valves, smoke detectors, and so on.

All beamlines at NSLS-II have one Front End (FE) shutter and at least one beamline photon shutter. They are also part of storage ring Personal Protection System (PPS). The beamline EPS needs to communicate with the PPS PLC through related interface signals. Besides, beamline EPS PLC needs to communicate with FE vacuum PLC and cryocooler PLC through specified interface signals.

NSLS-II BEAMLINE EPS HARDWARE DESIGN

The beamline EPS hardware is based on a Programmable Logic Controller (PLC). Each beamline at NSLS-II is designed to have its own EPS system which consists of only one PLC.

The EPS I/O signals can be divided into two categories based on their location and signal type. The first category of signals includes vacuum relay signals, smoke detectors, and motion limit switches. These signals are connected to the intelligent chassis or the vacuum chassis. All other signals are in the second category, and they are wired to remote I/O boxes, or Armor blocks. The EPS hardware is designed with these two categories of signals in mind.

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Intelligent Chassis

Each beamline has only one PLC, e.g. one controller, which resides in the intelligent chassis. This chassis is a 4U high, 19 inch crate. It contains one controller, power supply modules, network modules, I/O modules and other modules. Figure 1 shows the front/rear panel, and chassis module layout.

Figure 1: Intelligent Chassis Front/Rear Panel and Module Layout.

Two 1606 power supply modules are used in the chassis. One XLS240E provides 24 VDC for this chassis and one XLS480E provides 24 VDC for distributed I/O modules. The beamline EPS PLC uses CompactLogix 1768-L43 controller which requires 1768-PB3 power module. The EPS system uses two independent TCP/IP networks. The 1768-EWEB communication adapter provides EtherNet/IP web server over beamline instrumentation subnet while 1768-ENBT module offers EtherNet/IP bridge on private network. All of the PLC data gathering and commanding is on the private network. The instrumentation network handles the communication to users and main control. This assures reliable status and control of hardware on a beamline. I/O signals inside the rack are handled by two 1769-IQ32T and one 1769-OW8I modules.

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On the front panel of the beamline EPS intelligent chassis, there are four green/red LEDs indicating 24 VDC, Ethernet status, CPU status and I/O status separately. Based on the beamline requirements, this chassis is designed to provide connection for up to 6 vacuum gauge controllers, 6 vacuum pump controllers, one fast valve controller, four motion controllers and four smoke detectors. It also provides four 24 VDC outlets and four industrial Ethernet ports for the private network.

Vacuum Interlock Chassis

For beamlines with many vacuum components, additional vacuum interlock chassis are installed in vacuum controller racks, where needed. The vacuum chassis is the same size as the intelligent chassis. It has front and rear panels that are similar to the intelligent chassis. The chassis module layout can be seen in Figure 2.

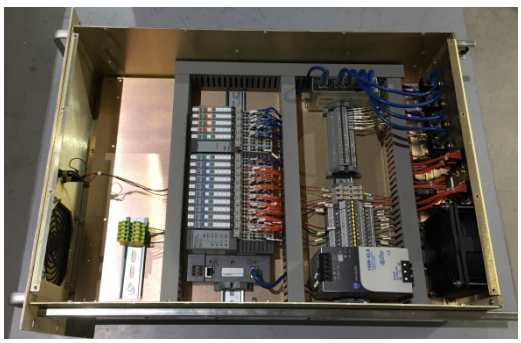

Figure 2: Vacuum interlock chassis module layout.

The I/O signals connected to vacuum chassis are wired to Allen Bradley (AB) 1734 point I/O modules which can be integrated with 1769 modules. The 1734-AENTR/B adapter provides connectivity to an EtherNet/IP network with two RJ-45 connectors for 2 port pass-through to support daisy-chain network topology. The vacuum chassis provides the same connection capacity as intelligent chassis, with the exception of the 24 VDC ports.

Remote I/O Box

Remote I/O box solution is adopted for I/O signals distributed along beamline. These I/O signals include temperature sensors, water flow sensors, limit switches, coils, and so on. The interface signals to PPS and FE vacuum PLC are also connected to I/O box. The number and location of the I/O boxes vary between beamlines. They are built and installed based on the I/O distribution and density. These boxes also provide enough room for future expansion.

Same as vacuum interlock chassis, the 1734 point I/O modules are installed in the remote I/O box. Figure 3 gives an example. These boxes are wired to the intelligent chassis for power and network connectivity.

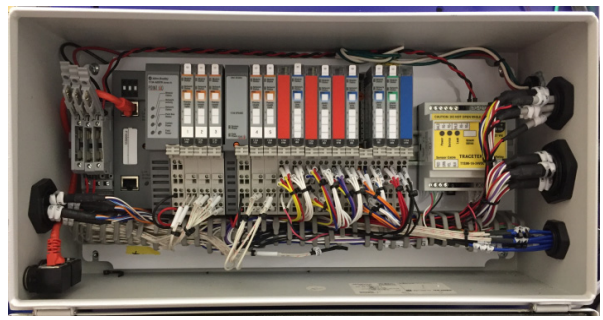

Figure 3: EPS remote I/O box module layout.

ArmorBlock

In the case of limited space and I/O signals, the 1732E ArmorBlock I/O modules are mounted locally to give a low cost solution. These modules offer various I/O points per module and are widely used on end stations.

NSLS-II BEAMLINE EPS SOFTWARE DEVELOPMENT

NSLS-II beamline EPS software development can be divided into three aspects: PLC programming, EPICS IOC (Input/Output Controller) development, and OPI (Operator Interface) development.

PLC Programing

The beamline EPS PLC is programmed with RSLogix 5000 version 20.01 to take protective actions in the case of detection of unfavourable conditions in the beamline. The 1768-L43 controller supports up to 16 tasks. In our case, two tasks run on the EPS PLC, continuous task (around 100 Hz) and periodic task (5 Hz). The continuous task contains PPS logic, vacuum logic, and other time critical logic. The periodic task includes temperature, water, network and other routines where fast response time is not as critical.

Add-on instructions, a powerful feature of RSLogix 5000, are created for components that are commonly used. They are customized instructions that created for sets of commonly-used logic. Add-on instruction are used for vacuum valves, photon shutters, temperature sensor, and flow sensor contain same functions. These instructions are re-used in other beamlines by exporting and importing them. This minimizes the programing effort.

The EPS logic is quite straightforward. Each NSLS-II beamline vacuum section generally is made up of one Code Cathode Gauge (CCG), one Pirani Gauge (TCG), one Ion Pump (IP) and bounded by Gate Valves (GV). Any detection of poor vacuum from the CCG or IP closes the two adjacent GVs, as well as an additional upstream gate valve. Most beamlines have some beam conditioning optics upstream of their monochromator. To protect the optics and gate valves, the FE shutter must be closed whenever any vacuum loss detected before monochromator. The FE shutter also must be closed in detection of coolant flow loss, temperature elevation, cryocooler loss, network disconnection and so on to

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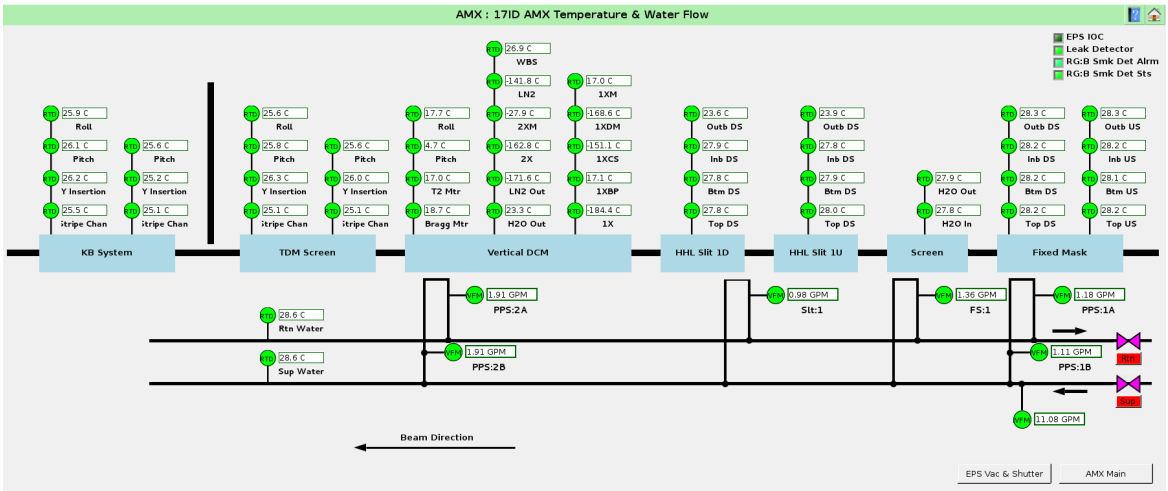

Figure 4: NSLS-II beamline EPS OPI example: AMX temperature and flow screen.

prevent the beamline from x-ray damage. The EPS PLC is also programmed to support interlock condition latch to remember status at the moment when interlock happens.

EPICS IOC Development

EPICS (Experimental Physics and Industrial Control System) [1] was chosen as the base control system software for all beamlines.

The NSLS-II EPS softioc runs on EPICS base 3.14.12.3 and shares the same host as other softiocs. The host uses a cost-effective Linux server, such as HP Proliant DL 360, IBM system x3550. It runs Debian operating system and is equipped with all required EPICS packages. These packages include base, extension, synapps, iocstats, EtherIP, caputlog, vacuum, areadetector, and many others.

The EPS softioc is built based on EtherIP support which interfaces with AB ControlLogix 5000 PLCs via Ethernet. Besides that, it also contains autosave, iocstats, caputlog as these are defined in the NSLS-II beamline control standard IOC configuration. Beamline specific access security file is loaded to protect IOC database from any unauthorized Channel Access client. The softiocs are configured to automatic start using procServ with sysv-rc-softioc package.

OPI Development

CSS (Control System Studio) [2] is the base GUI system for all NSLS-II beamlines consistent with accelerator. It is an Eclipse-based collection of tools to monitor and operate large scale control systems. It's an excellent platform for EPICS control system and has been widely used in the accelerator community. It provides many tools, for instance, Best OPI Yet (BOY), Best Ever Alarm System Toolkit (BEAST), data browser, etc. BOY is an operator interface development and runtime environment. BEAST is the alarm management tool. Data browser is a trending tool that provides an easy way to view and retrieve archived data.

Control and monitoring of the PLC is available through the OPI screens and offers the following functions: 1) Monitoring: EPS alarm status, beamline GV status, temperature/flow values/trip points status, pressure trip point status, cryo-cooler ready/alarm/enable status, pneumatic actuator position status, and conductivity meter readings; and 2) Control: beamline gate valves and pneumatic actuator insertion/retraction. Figure 4 shows the flow and temperature screen of one beamline.

The important EPS parameters/status mentioned above are archived in EPICS Archiver Appliance [3] which is the archiver for NSLS-II. Each beamline has its own archiver server.

NSLS-II BEAMLINE EPS TESTS

Several types of tests are done on the beamline EPS system. Once the intelligent chassis and vacuum interlock chassis are received from the manufacturer, all chassis are checked prior to the installation in the rack to verify the proper wiring. After all of the field wiring is completed, the PLC logic program and GUIs are tested with customized dummy loads and simulators. The final test with the completed beamline is carried out before beam commissioning to make sure the hardware and software work properly.

SUMMARY

The NSLS-II beamline EPS provides a robust, reliable and extensible solution for various beamline requirements. The two independent networks assure reliable status and control of hardware on a beamline. The remote I/O box and ArmorBlock provides an easy way for future expansion. The user friendly CSS GUIs provides detailed information to beamline scientists and users.

REFERENCES

[1] EPICS, http://www.aps.anl.gov/epics

[2] CSS, http://cs-studio.sourceforge.net.

[3] Archiver Appliance, https://slacmshankar.github.io/epicsarchiver_docs/index.html.