Third Generation Synchrotron Facility

The National Synchrotron Light Source II (NSLS-II) will require a high degree of precision electronics to run properly. At these early stages, it is best to get the control system in place, so that final configurations can be assured to work.

The National Synchrotron Light Source II (NSLS-II), being built by Brookhaven National Lab (BNL), is a $912-million electron accelerator project funded through a grant from the Department of Energy. Additional funding from the American Recovery and Reinvestment Act has helped to keep the project on track to be completed well ahead of the June 2015 scheduled date. Research from NSLS-II will focus on developing the world’s next generation of sustainable energy technologies, based on materials that have not been designed or fabricated yet. The facility will provide researchers with the capabilities needed to study the properties and functions of complex materials.

Brookhaven’s present synchrotron is used by over 2000 researchers who come from over 400 universities, government labs, and private companies each year. They study materials from computer chips to biological molecules. To probe smaller and smaller details of sample materials, an ultra-intense, highly focused light is needed. NSLS-II will be the only light source capable of providing scientists with images down to a nanometer in size.

The engineering team for the new synchrotron facility considered the major parts of the facility, and what they would need to control them. Basically, the synchrotron produces light by accelerating electrons near the speed of light into a circular path controlled by a series of magnets. As the electrons turn, photons of light are given off in the form of infrared, ultraviolet, and x-ray light, which is sent down pipes called beamlines to areas where scientists conduct their experiments. The major parts include an injector complex that generates and accelerates the electrons and is made up of an electron gun, linear accelerator, and booster ring; a storage ring that circulates the electrons while they radiate synchrotron light; and beamlines that transport the light to user experiments.

NSLS-II will accommodate approximately sixty beamlines using about 30 straight sections for insertion device sources. Although the synchrotron does not rely on motion systems for operation, the beamlines, or experimental stations, do depend on motorized systems to steer and focus their x-ray beams, as well as to position detectors and samples. Each beamline will have an average of 100 motorized axes, which means that over the completed facility, there are expected to be 6,000 axes of motion.

The Brookhaven engineering team selected to use repackaged Geo Brick LV multi-axis controllers, designed and manufactured by Delta Tau Data Systems as the motion controllers. The repackaging that Delta Tau facilitated was to create a 19” rack-mount enclosure for the LV, with connectivity specified by BNL. The motion controllers will accurately and repeatedly move several optical components that act to steer (mirrors), shape (slits), and focus (mirrors and lenses) the beams of the x-rays. The number, type, and location of these optical components will vary depending on the optical requirements of a given beamline. In general though, all optical
elements have some motorized degrees of freedom. Overall, BNL purchased 120 Geo Brick LV controllers to facilitate nearly 1000 axes of motion.

An example of a high-precision application inside the synchrotron would be an insertion device (located inside the storage ring), which controls two jaws of magnets with four axes each (two upper and two lower), over a range of 200 mm. This would be handled at a precision of 0.001mm, while in the presence of magnetic and mechanical forces in excess of 50 kN (or around five metric tons). Also, each beamline relies on devices for selecting a single wavelength of x-rays (called monochromators), which must provide angular resolutions of one microradian or less (or 57 millionths of one degree). The positions of these devices are dictated using high-precision electronic stepper motors, as well as some piezoelectric motors for fine adjustments.

The Delta Tau controllers will also play a key role in data acquisition systems on the beamlines, as they will issue triggers to detectors at precise positions, or very accurately capture positions of axes in response to external triggers. The controllers may also be interfaced with other systems, like photon shutters, where the controller will open and close the shutter in response to various conditions to illuminate an experiment sample.

The configuration will include the LV controller as well as the necessary axes boards, I/O boards, communication interfaces (USB, Ethernet, etc.) and any other interface boards selected from the variety available from Delta Tau. This includes virtually any type of feedback device and any communication method that is needed for the final design.

Basic motion control specs include, four or eight axes of simultaneous servo/stepper control with multitasking of up to 16 motion programs and 64 asynchronous PLC programs. All axes can operate independently or be coordinated in any combination. The controllers use a user-friendly, high-level programming language, and offer a standard 128K by 24 SRAM memory (for programs, variables, and tables). True S-curve accel/decel operation provides jerk-limited profiles, while hardware position capture and compare offers very high precision.

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*NSLS-II photos courtesy of Brookhaven National Laboratory*

Pic-1: Rendering of the National Synchrotron Light Source II, currently under construction at Brookhaven National Laboratory. NSLS-II is a new state-of-the-art medium energy storage ring designed to deliver world leading brightness and flux. The facility will be able to produce x-rays up to 10,000 times brighter than those produced at NSLS today.

Pic-2: National Synchrotron Light Source II's first girder -- a 14-foot, 8-ton structure holding multiple magnets -- is being installed in the accelerator ring.
Pic-3: 826 high-precision magnets will form the main accelerator ring of the National Synchrotron Light Source II. A beam of electrons will be shot through the center of each magnet, where powerful magnetic fields will contain and steer the particles in a nearly circular path. Light emitted by electrons traveling around the ring will be shunted to beamlines, a collection of scientific instruments where experiments will be conducted.

Pic-4: 120 Specially packaged Geo Brick LV multi-axis controllers, with special interface boards and connector cables are used in the NSLS-II synchrotron to control nearly 1000 axes of motion.