NSLS-II INSERTION DEVICE CONTROLS PLAN

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Abstract

Controls on insertion devices (IDs) are usually comprised of motor controls, encoders, cooling water for in-vacuum devices, various sensors such as limit switches and temperature sensors. Interlocks are provided independently from the device controls. They have been considered "slow" control elements and very little attentions have been paid to the response and latency of ID controls. However, current project scope of National Synchrotron Light Source –II (NSLS-II) project demands very tight tolerance of beam movement of submicron level. More frequent use of elliptically polarizing undulators (EPUs) also requires synchronized movement between gap and phase motions to ensure the stability. Furthermore, future demand for synchronization of ID states and beam line components prompt more sophisticated schemes. Synchronous Device Interface (SDI) [1] is originally proposed for fast feedback I/O interface and integration of some ID controls to SDI is considered as well as other options.

INTRODUCTION

NSLS-II will provide the electron beam with sub-nm.rad horizontal emittance and 500mA of electron beam current with top-off capability by 2015. Vertical electron beam size in the center of a straight section is approximately three microns. Therefore, this ring requires submicron level of beam stability even though many insertion devices constantly change the magnetic field from the devices. Four types of insertion devices are planned at the initial stage of the operation. Damping Wigglers (DWs) have a nominal peak field of 1.8T and two units of a length of 3.4m will be installed in a long straight (LS) section. Three Pole Wiggler (3PW) will be installed at the end of a dispersive section to accommodate NSLS BM users at the expense of small amount (~10%) of beam emittance increase when 15 of them are installed. The main hard X-ray undulator source will be "cryo-ready" In-Vacuum Undulators (IVUs) [2], and out-of-vacuum Elliptically Polarizing Undulators (EPUs) will cover soft X-ray regions. Apple-II type EPU [3] which is most commonly used permanent magnet based device requires up to eight motors whose motions must be coordinated. With gap / phase change, the corrector magnets for IDs require very intricate power supply controls to maintain the very stringent beam stability requirements

OBJECTIVES

IDs are the only accelerator components which can be tailored to the needs of corresponding beam line. However, close coordination of motion of an ID and that of beam line components has been mostly ignored (recently Swiss Light Source made an attempt to speed up the coordination in IOC level). This is partly due to the political / organizational reason to divide accelerator segment and beam line side. Another reason is that an ID and beam line components are developed independently by different groups with some time delay on the schedule. As a result, the coordination of ID gap v.s. energy setting of a monochromator is done in the control system level at best. At NSLS-II, the ID group plans to provide the ID synchronization options in lower equipment level upfront before any type of beam line is designed.

The followings are the types of requirement for ID controls we envision:

A) High precision low level power supply control for corrector magnets for feed forward table look-up.

B) Closed loop gap adjustment for varying phases for an EPU to cope with changing forces between upper magnetic arrays and lower ones.

C) Semi-real time (<10msec) update of gap / phase values of an ID in a remote location, i.e. at the location of monochromator controller or other beam line components. For conventional IDs, those values are encoder readings fed directly to the motor controller. For IVUs, in-situ gap monitor by a commercial, high-precision, LED-based optical micrometer [1] is likely to be the signal for the gap.

D) For electromagnetic EPUs or orbit switching which are planned for the later phase of the project, swift adjustment for multiple power supplies to maintain the stable closed orbit.

ID CONTROL FEATURES

Generic ID Control Design

The control system (CS) for an ID is used to manipulate and monitor all signals for a specific device. This includes motion control, and motion control related safety signals. Often other device-specific features are also included in the CS. Controlling corrector magnets, implementing specified sequence of motor moves, lookup tables for motors position and tilt switches are common demands in such systems. Temperature sensors, cryogen flow sensors and in-situ gap monitoring system could be added to more sophisticated IVUs.

In most ID control systems there are three elements of the system, which process and produce control signals. These are:

- Input-Output Controller (IOC)

This is the control system node on which the server side of the control system software is running on. It communicates with other parts of the ID control system (i.e. motion controller) and also with outer world. For Experimental Physics and Industrial Control System (EPICS) IOCs, there are two controller candidates among NSLS-II standard equipment for ID controls. One is a conventional VME (Motorola 3100) and the other is micro TCA (MTC5070) both running RTEMS as an RTOS.

- Motion Controller

Motion controller controls the motors based on the commands it receives from the IOC and on the read backs it gets from the position sensors (linear absolute encoders are most common in the latest devices). Most motion controllers also provide necessary inputs for limit switches and implement handling of critical conditions at limits.

For an Apple-II type EPU, a controller with up to 8 axes is preferred. We have tentatively selected Parker ACR 9000 and Delta-Tau Geo Brick LV for motor controller since both has synchronous serial interface (SSI) encoder inputs which many absolute linear encoders require, and all 8 axes have independent position synchronized triggering features.

- Interlock Logic

By the term 'Interlock logic' we mean a hardware component(s) which is also present in most ID control systems and monitors interlock signals (not necessary only motion control related) and takes appropriate actions. Sometimes the outputs from the motion controller are also processed by the Interlock logic, which prevents moves in case of the predefined limit conditions. Interlock logic is often realized with either industrial PLCs or custom cards, specially developed for particular type of insertion devices or some other solution. This system is preferred to be independent from CS for regular operations.

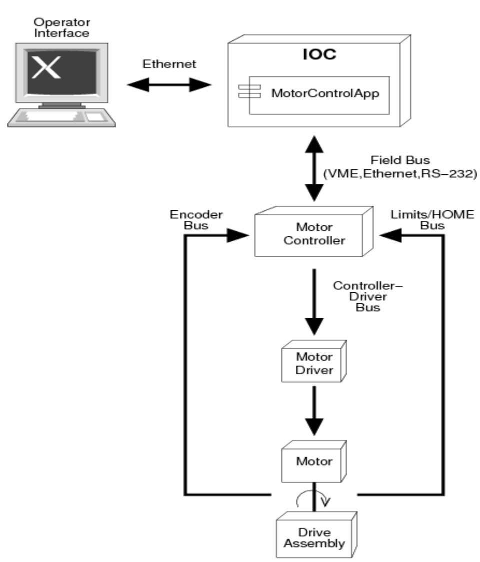

Figure 1: A typical motion control system.

- Software

Common software components are: device drivers, control system software, motion control programming, power supply control, graphical user interface (GUI) and interlock logic.NSLS-II has decided to employ EPICS for CS software. EPICS does not have a standard capability for data base (DB) accessibility. NSLS-II controls group will provide DB infrastructure. Default GUIs for EPICS are X-server based and their capability for sophisticated graphics is fairly limited. Therefore the use of Java based GUI is also under consideration.

Figure 1 shows a typical motion control system configuration.

SYNCHRONIZATIONS

Motion Synchronization

In the case of Apple-II type EPU, the undulator gap has to be constantly adjusted while the phase relations are changed. This is due to varying attractive force with different phase positions. In some case, the gap tapers must be simultaneously adjusted. This relation between force and phase is not a single function, but two different sets of functions for two different modes (symmetric shift and anti-symmetric shift). Since this adjustment requires in the time scale of msec, the control loop must be constructed in the controller level. Since each ID has its dedicated motor controller, this task could be solved with proper selection of controller.

The idea of synchronization of ID status and beam line components such as a double-crystal monochromator (DCM) has been considered for a long time. With the introduction of top-up injection, the necessity for fast scan has somewhat diminished. However, the need to shorten the spectral scan is always present, not only for scientific reason, but also productivity improvement of the users.

DCMs are utilized to select a narrow region of energy from the relatively broad spectrum produced by an insertion device. Often operating on the principle of Bragg diffraction, the output from a DCM may form the input to subsequent optical elements at a beam line. Assuming the use of a DCM, there may be eight or more axes of motion:

- Bragg Angle
- Crystal Roll (crystals 1 & 2)
- Pitch (crystal 1 or 2)
- Yaw (crystal 1 or 2)
- Vertical Translation (crystal 1 or 2)
- Lateral Translation

Similarly to the manner in which an insertion device may be thought of as having a single, virtual gap axis, a DCM may be thought of as having a virtualized energy axis of motion. There may be several physical axes simultaneously involved in the actual motion to select an energy, but it may be helpful to consider this concerted motion as occurring along a single, virtualized energy axis. This function of energy v.s. gap is a non-linear function whose shape depends on each device’s parameters.

Scenario 1: Single controller option

Figure 2 shows the simplest configuration for motion synchronization. One multi-axis controller will perform the necessary task. Even though this option may be simplest, it is unlikely that big organization such as NSLS-II will allow the control of devices in both accelerator and beam line segments with single IOC and motor controller.

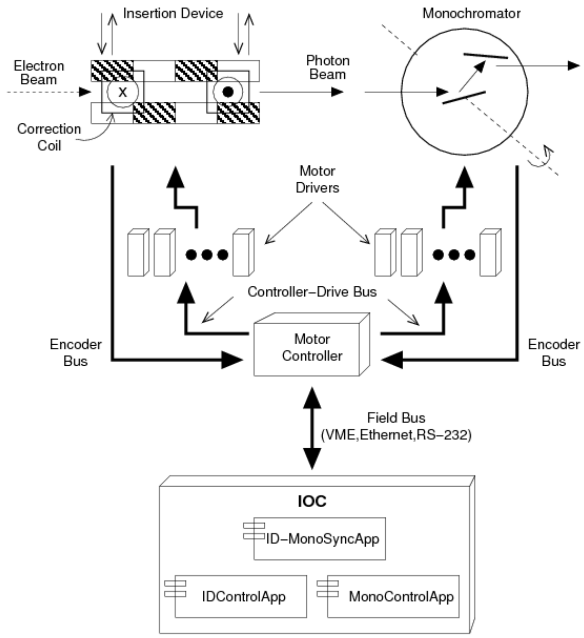

Figure 2: Single IOC / motion controller option.

Scenario 2: Dual controller / dual IOC option

Alternative solution is to employ a separate IOC and a controller for each segment like most of major facilities do. However, the motion controllers have a dedicated link which is used by the controller for a DCM to monitor the states of the ID in semi-real time (~1msec). Hence the motion synchronization is done in the lower level without going through IOCs. We consider using a motor controller which has high speed triggering on all 8 axes. It can be configured to do a UDP status broadcast to one specific IP address. The broadcast can be configured to contain only the encoder position readings, typically in DSP format. Another way could be a TTL connection from the controller to the counter which delivers the position synchronized trigger. Figure 3 illustrates the idea of dual controller system with the dedicated link shown in the orange arrow. The direction of the arrow implies that the beamline side monitors the ID status.

PS SYNCHRONIZATION

NSLS-II ring imposes strict beam stability criteria. At the center of a short straight section, the electron beam size is 30 microns horizontally and 3 microns vertically. Hence, very precise feed forward controls of power supply for correction coils is required. It has been estimated that no smaller than 5 G.cm variation during gap / phase change in terms of the integrated first integral could be tolerated.

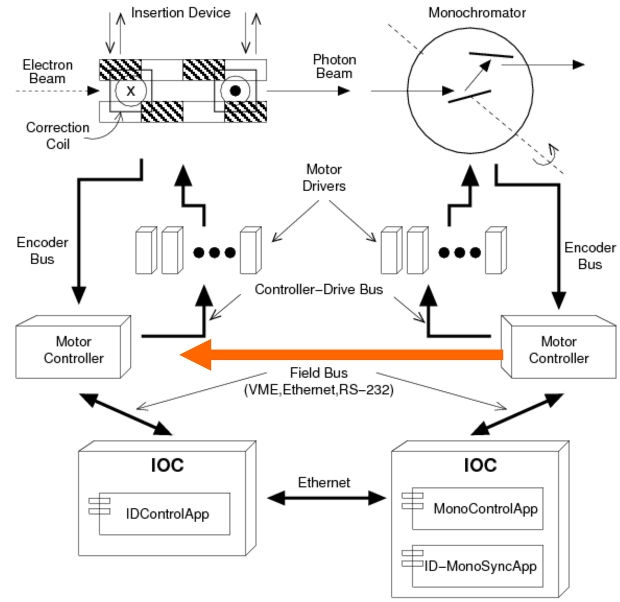

Figure 3: Dual IOC / dual motion controller option.

A new fast communication protocol called synchronous device interface (SDI) is being developed at NSLS-II. SDI will also be extended to the power supply control system, where power supply controllers (PSC) and cell controller form a ring network for power supply data distribution. Even though the standard feed forward PS controls could be handled by a single controller, coordination of multiple PSC with minimal latency may require SDI. We are investigating the possibility of using SDI network to coordinate the PSC for EM-EPUs and fast feed back PSs.

SUMMARY

NSLS-II insertion device controls are being designed to incorporate the more efficient synchronous motions between ID state and beam line components from the beginning of the project.

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