INSERTION DEVICES CONTROL PLANS FOR THE TAIWAN PHOTON SOURCE

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Abstract

Insertion device (ID) is a crucial component in third-generation synchrotron light sources, which can produces highly-brilliant, forward-directed and quasi-monochromatic radiation over a broad energy range for various experiments. In the phase I of the Taiwan Photon Source (TPS) project, ten insertion devices (IDs) will be planned, constructed, and installed for the first seven beamlines. The control system for all the IDs is based on the EPICS architecture. The main control components include the motor with encoder for gap adjustment and phase moving (only for Elliptically Polarizing Undulator), trimming power supply for corrector magnets, temperature sensors for ID environmental monitoring and baking (only for In-Vacuum Undulator), and interlock system (limit switches, tilt sensors) for safety. The progress of insertion device control plans will be summarized in this report.

INTRODUCTION

The TPS plan to install one set of EPU46, two sets of EPU48 and seven sets of IU (In-Vacuum Undulator) which are arranged in seven straight sections to fulfill various experimental requirements in the first phases of TPS completion. The parameters of IDs are shown in following table. The Table 1 presents in summary the parameters of insertion devices and its motors used [1].

Table 1: Insertion Devices Plan for TPS Phase-I

3 GeV		EPU48	EPU46	IU22	IU22	IUT22
Photon Energy (keV)	HP	0.45-1.5		5-20	5-20	5-20
	VP			-	-	-
Period (mm)		48	46	22	22	22
Nperiod		67	83	95	137	137
B_y (T)		0.85	0.83	0.79	0.79	0.79
B_x (T)		0.59	0.59	-	-	-
$K_y$max		3.81	3.57	1.54	1.54	1.54
$K_x$max		2.6	2.5	-	-	-
L (m)		3.2	3.57	2	3	3
Gap (mm)		13	13	7->5	7->5	7->5
Number of devices		2	1	2	4	1
Number of gap/(phase) motors		2/(4)	4/(4)	1	1	2
Type of motor		Servo motors		Stepping motors		
Main body vendor		In-house	ADC*, In-house	Hitachi-Metals		
Controls		TPS standard insertion devices control environment				
Remarks		Collinear Installed	-	-	Collinear Installed	with taper

* ADC delivers frame and magnetic blocks. Mechanical improvement, shimming, and controls were done in-house.

The main hard X-ray undulator source will be produced by IU22, and out-of-vacuum EPU48 and EPU46 will cover soft X-ray regions. EPU48 and EPU46 which are most commonly used permanent magnet based device requires up to six or eight motors whose motions must be coordinated. With gap / phase change of ID, the corrector magnets require very intricate power supply control to maintain the very stringent beam stability requirements.

For conventional IDs, encoder readings are fed directly to the motion controller. Semi-real time (approximate 5 msec) update of gap / phase values of an ID in a remote location, i.e. at the location of monochromator controller or other beamline components.

Control system for all insertion devices are done by NSRRC control team for economic reason, delivery a similar control environment is the goal. Insertion devices of TPS phase-I are shown in Fig. 1.

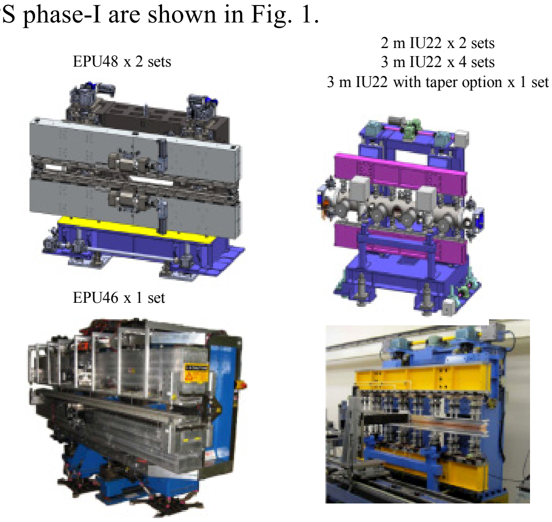

Figure 1: Insertion devices of TPS in the phase-I.

INSERTION DEVICES CONTROL ENVIRONMENT

Insertion devices project for the TPS phase-I is in proceed. All insertion devices will share the same control environments even these devices are in-house developed and/or contracted by vendors. The control environment will support the operation of insertion devices.

Hardware Architecture

Control plan for the phase-I insertion device is based on the standard TPS cPCI EPICS IOC. Motion controller is based upon Galil DMC-40x0 series Ethernet based motion controller [2]. The controller is a full-featured motion controller packaged with multi-axis drives in a

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compact, metal enclosure. Motion controller controls the motors based on the commands via Ethernet. It receives commands from the EPICS IOC to handle motor motion and read encoder positions, limit switches, position error and other states for monitor and software protection.

The motion controller can deal with servo motor (EPU46, EPU48) and stepper motor (IU22). Closed loop gap adjustment is needed for varying phases of EPU48 and EPU46. It can be coped with changing forces between upper and lower magnetic arrays. All motion axes included a synchronous serial interface (SSI) optical encoder connect to the motion controller directly. Each motion axis accompany with limit switches for over travel protection. Synchronize motion amount gap axes is essential to prevent tilt of the beam.

The hardware configuration for TPS ID control is shown in Fig. 2. The system includes cPCI EPICS IOC, 128 bits DI/DO module, ADC/DAC IP (Industry Pack) modules, motion controller, temperature monitoring solution and RS232/422/485 based device of the insertion devices frame. High precision power supply is used for controlling the corrector magnet through the feed forward look-up table. Current design includes the control interface for the beamline. The IU22 controls should include ion pump and ion gauge interface.

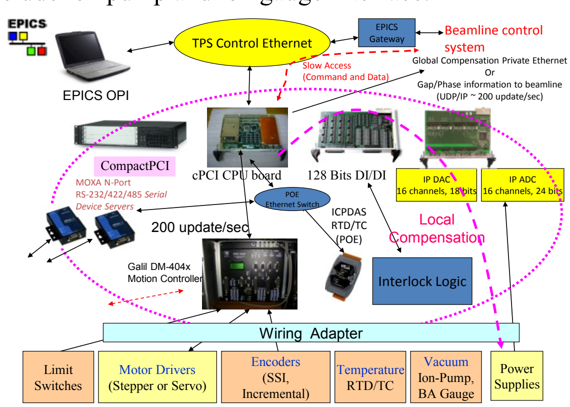

Figure 2: Basic hardware configuration for TPS insertion devices in Phase-I.

Software Configuration

The status of all axes updated by the motion controller, DMC4000 series, and its time period can be configured to 5 msec. To achieve the update rate in EPICS, an interrupt produced by a kernel driver is involved. It is to trigger the scanning of all position related process-variables (PVs). The kernel driver and char device driver are installed for the data access for EPICS processes and a data receiver and for passing interrupts. The data receiver process running in background receives axes data then flush into the kernel memory created by the kernel driver, as shown in Fig. 3. With pciGeneral device support [3], EPICS processes directly access the same kernel memory as well. An interrupt counter PV, its SCAN filed is set to "I/O Intr" and set FLNK field to the first PV of the position related records to start scan. For instance, an EPU, which consists 2 axes gap and 4 axes phase, there are about 300 position related PVs and status PVs. They are mostly configured into the 5msec scan list. It includes software max/min limit checking and the tilt of the gap; the motors are abort immediately if the values go over limits. The feed-forward correction of the magnetic field can be done at the same rate in the IOC or the one provides global correction. The streamDevice and asynDriver of EPICS are used for sending position commands to the motion controller.

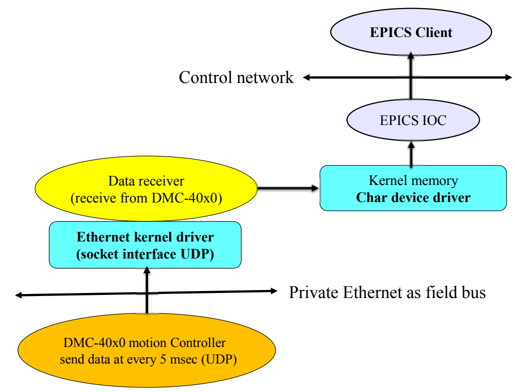

Figure 3: Relationship between major software components.

Residue Field Compensation

Stringent beam stability requirement of the TPS storage ring ID straight imposed field error should be controlled to less than a few G.cm of the first integral during the gap/phase change could be tolerated. As shown in Fig. 4, local compensation by using look-up table to derive corrector magnet is essential. The look-up table could be updated at rate up to 200 times per second.

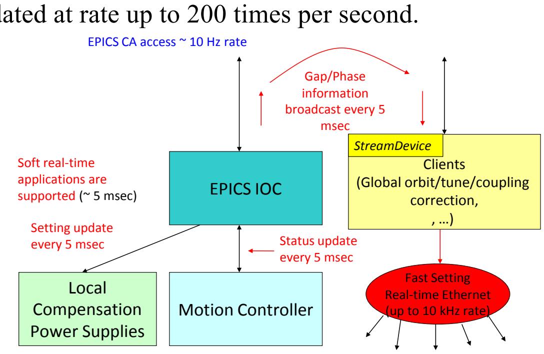

Figure 4: Local and global compensation schema for insertion device.

Synchronization Among Motion Axes

The synchronization between axes is done by the motion controller, there is a start-to-move command sent behind target position of demanded axes. In other words, the PVs of target position and start-to-move commands are separated. For instance, the gap of an ID controlled by two axes motors, the control loop can be done at every 62.5 µsec in the motion controller, DMC40x0 series.

Protection

There are three levels of protection mechanism implemented include circuit, motion controller and EPICS IOC. All protection devices will split into several isolated outputs to hardwired logic, motion controller, and EPICS IOC to guarantee without single point of failure happened. The hardware level use the status of limit switches and tilt sensors combined with logics implement by hardware to provide hardwired protection to prevent further motion if extreme conditions happened. The protection at motion controller and motor driver use limited switches, encoder values, stall, over drive, over temperature …etc.

All protection devices include limit switches, tilt sensors will split and input to the EPICS IOC also. An interlock by EPICS sequencer coded by SNL can also provide another level of protection. An additional to sniffer the value of the SSI encoder is also possible by the industry pack SSI listen only interface.

Interlock logic means 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 the move 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 control system for regular operations.

Graphical User Interface

The user interface is implemented by using EPICS EDM and will be integrated into CSS (Control System Studio). The preliminary EDM page is shown in Fig. 5. A main page with ID images is for general operation and a detail EDM page shows all status and adjustable PVs which are PID parameters, torque limit … etc.

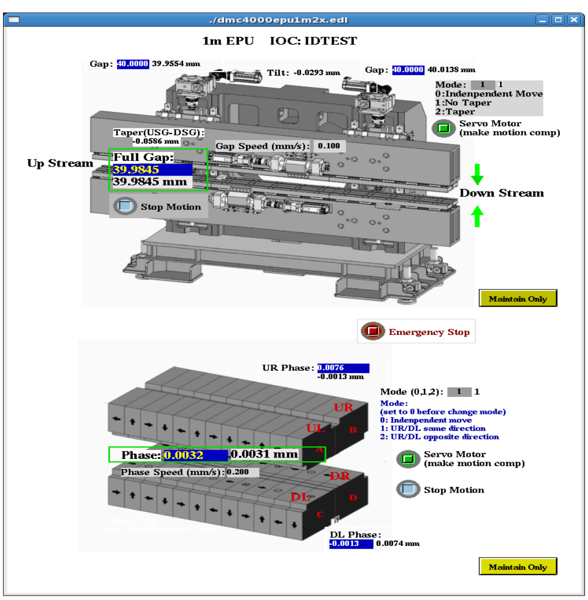

Figure 5: The preliminary GUI of the insertion devices.

BEAMLINE SUPPORTS

Beamline controls and the accelerator controls are responsible by different groups. ID control is responsible by accelerator controls. To allow the beamline to set a gap/phase demand position for beamline scanning automatically, an EPICS gateway for each beamline is allocated to provide necessary connectivity and isolation. Thus the control of an insertion device from a beamline is implemented across the gateway. This allows accelerator control system to implement enable/disable control on the beamline based demands.

On-the-fly experiments which synchronize ID gap and beamline monochromator energy scan are interesting recently to increase productivity and to meet requirement of scientific goals [4-5]. Some design used the monochromator as master, the ID just follow it during the scan. The ID can be as master also, the beamline devices just follow its. Current agreement between ID controls and beamline controls plan to set the ID as master to provide ID information, beamline monochromator just follow to do the energy scan. Standard ID control provides gap/phase information to the beamline IOC and/or monochromator controller by channel access via EPICS gateway and/or an dedicate Ethernet which connect to the ID controller. Current test results can be achieved 200 Hz update rate with 1 msec jitter. Since the optical encoder is used for ID motion controller, if beamline side interests to read optical encoder directly, it can used SSI listen only interface as sniffer without problem. Tightly coupled the ID control and monochromator in the motion controller level is also possible which need a special synchronization design if necessary.

SUMMARY

TPS insertion devices controls are in implementation stage. Prototype test for 1 m EPU test bed was done. Various EPICS supports were developed. Contracted of IU22 by magnet group are in proceed continue, first delivery for two 2 m long IU22 will in June 2012. Frame of EPU48 will available no late than end of 2012. Controls integration will be started from the third quarter of 2012. Controls for all phase-I insertion devices are scheduled to finish in 2013.

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