STATUS OF THE TPS INSERTION DEVICES CONTROLS

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Abstract

The Insertion devices (ID) for Taiwan Photon Source are under construction. There are eight insertion devices under construction. These devices include in-vacuum undulators with or without taper, elliptical polarized undulators. Control framework for all IDs was developed. Using common hardware and software components are as possible. Motion control functionality for gap and phase adjustment supports servo motors, stepper motors, absolute encoders, and protection. The control system for all IDs is based on the EPICS architecture. Trimming power supply for corrector magnets and phase shifter control functionality are also addressed. Miscellaneous controls include ion pumpers and BA gauges for vacuum system, temperature sensors for ID environmental monitoring and baking, limit switches, emergency button. User interface for ID beamline users are included to help them to do experiment, such as ID gap control and on-the fly experimental. The progress of IDs control system will be summarized in the report.

INTRODUCTION

The TPS is planned 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 phase of TPS project.

Two IU22 which is 2 meter long and two EPU48 have been delivered to NSRRC. The control system of IU22 is developed in-house and used to support filed measurement of two IU22s in the laboratory including gap motion, vacuum pressure and temperature reading/archiving for baking, interlock system, GUI development and so on. The control system of EPU48 is developed including gap/phase motion, protection system (hardware and software) and GUI development. Insertion devices of TPS phase-I are shown in Fig. 1.

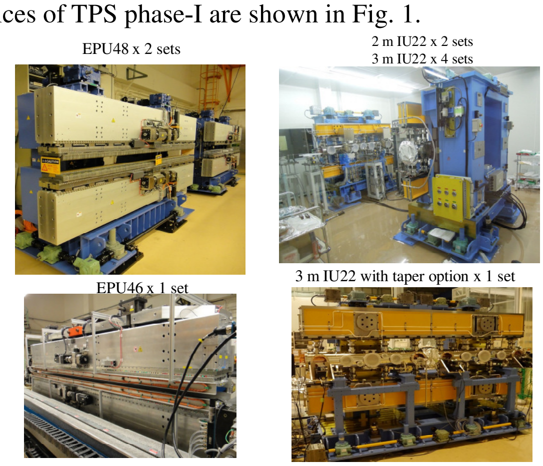

Figure 1: Insertion devices of TPS in the phase-I.

The main hard X-ray undulator source will be from 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, the corrector magnets for IDs require very intricate power supply controls to maintain the very stringent beam stability requirements.

The parameters of IDs are shown in Table 1. Features related to control of the insertion devices and its motors used [1-3] are summarized.

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	13.5	3.5	5	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	Servo motors	
Main body vendor		In-house	ADC*, In-house	Hitachi-Metals		
Controls		TPS standard insertion devices control environment (In-house)				

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

Control system for all insertion devices are developed in-house by NSRRC control team to achieve the goal to deliver a similar control environment and economically.

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 contract to vendors. The control environment will support the operation of insertion devices.

Hardware Architecture

Control 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 [4]. The controller is a full-featured

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motion controller packaged with multi-axis drives in a 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, 3 meter long IU22/IUT22) and stepper motor (2 meter long IU22). Closed loop gap adjustment is needed for varying phases of EPU48 and EPU46. Control rack layout of IU22 is shown in Fig. 2. It can be coped with changing forces between upper and lower magnetic arrays. All motion axes include 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.

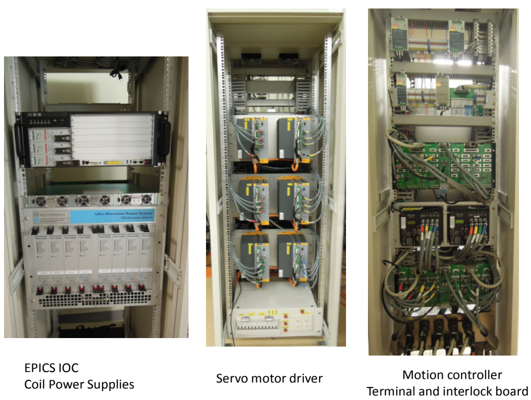

Figure 2: Control rack layout of EPU48 for TPS.

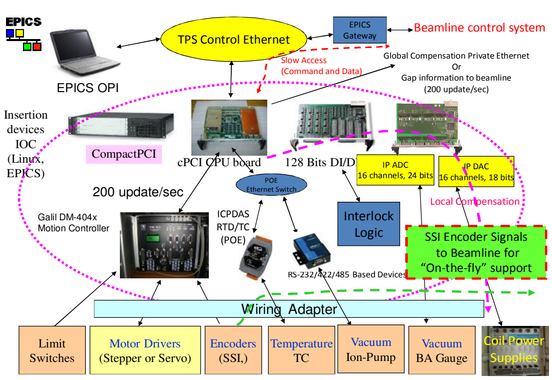

Figure 3: Basic hardware configuration for TPS insertion devices in Phase-I.

The hardware configuration for TPS ID control is shown in Fig. 3. The system includes cPCI EPICS IOC, 128 bits DI/DO module, ADC/DAC IP (Industry Packs) modules, motion controller, temperature monitoring solution and RS232/422/485 based device of the insertion devices frame. High precision power supply is used for coil magnet control. Current design includes the control interface for the beamline. The IU22 controls should include ion pump and ion gauge interface. Control rack layout of IU22 is shown in Fig. 4.

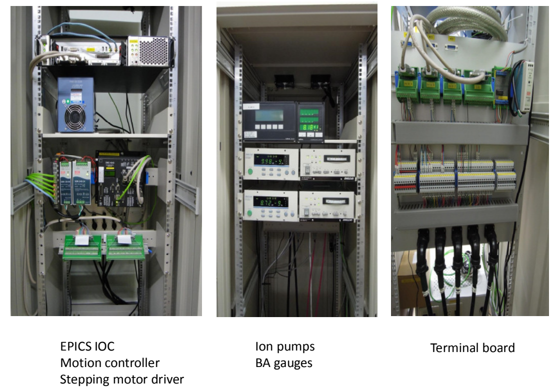

Figure 4: Control rack layout of IU22 for TPS.

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. 5. With pciGeneral device support [5], 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 EPU48, 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.

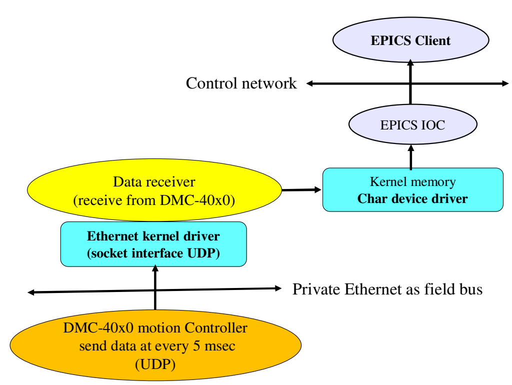

Figure 5: Relationship between major software components.

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Protection

There are three levels of protection mechanism implemented including 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 hardware 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 and etc.

All protection devices including 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.

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 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 control system for regular operations.

RESIDUE FILED COMPENSATION

Due to stringent beam stability requirement of the TPS storage ring, ID straight imposed field error should be controlled to less than a few G.cm so that the first integral during the gap change could be tolerated. Local compensation is performed by using lookup table to drive horizontal and vertical corrector magnets and long coil of ID. The look-up table could be updated at rate up to 200 times per second. The prototype EDM page for local compensation of IU22 is shown in Fig. 6.

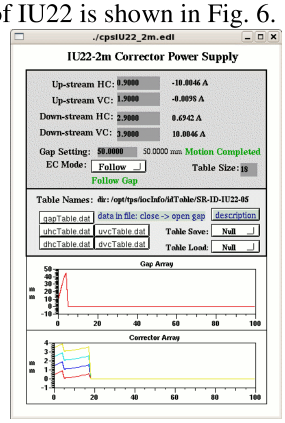
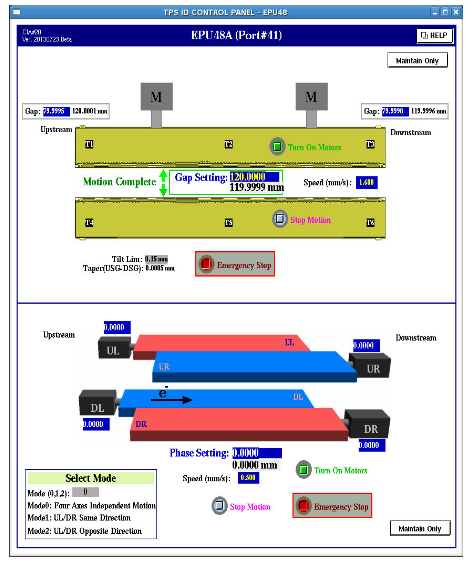


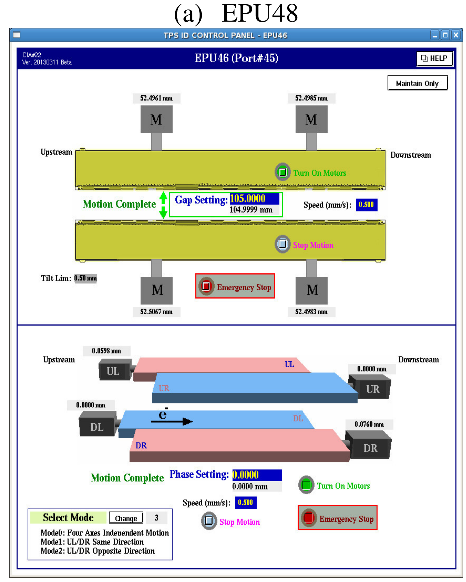
Figure 6: Local compensation prototype for IU22.

GRAPHICAL USER INTERFACE

The graphical user interface is implemented by using EPICS EDM and CSS (Control System Studio). Fig. 7 has shown the preliminary main page of EPU46 and EPU48. The preliminary main page of IU22 is shown in Fig. 8. Main pages of IU22, EPU46 and EPU48 are for general operation and maintain only page shows all status and adjustable PVs which are PID parameters, torque limit, speed and etc. Fig. 9 has shown the preliminary baking monitor GUI of IU22. The Data Brower of CSS is used for IU22 baking archiving data display, as shown in Fig. 10.



(a) EPU48



(b) EPU46

Figure 7: The preliminary GUI of EPU48(a); EPU46(b).

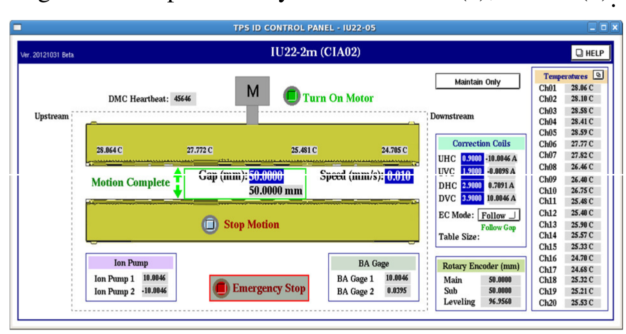


Figure 8: The preliminary GUI of IU22.

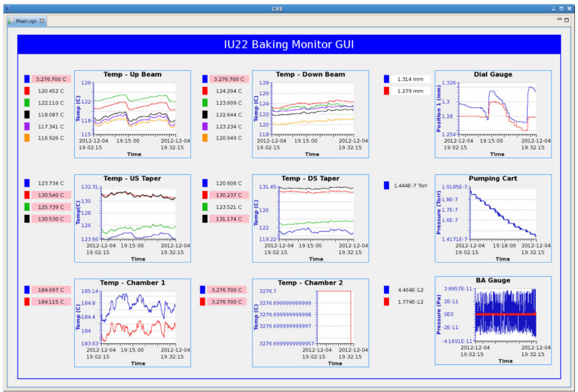


Figure 9: The preliminary baking monitor GUI of IU22.

Figure 10: Using Data Brower of CSS for IU22 baking archiving data display.

BEAMLINE SUPPORTS

ID controls are responsible by accelerator control team. Beamline controls are handled by beamline group. To allow the beamline to set a gap demand position for beamline scanning automatically, an EPICS gateway for each beamline is allocated to provide necessary connectivity and isolation.

On-the-fly experiments which synchronize ID gap and monochromator energy scan are interesting recently to increase productivity and to meet requirement of scientific goals [6-7]. 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.

There are two schemes to provide gap information of ID for on-the-fly experiments, its can access via computer network access or directly send SSI encoder signals through fibre link:

- Beamline or experiment station computer can read the gap position over the network through EPICS PV channel access (100 updates/s or more).
- The control system can provide clock and data hardware signals of absolute SSI encoder to the beamline or experimental station via optical fibre link (1000 update/s). Gap value of U50 for on-the-fly experiments via directly send SSI encoder hardware signals through fibre link in TLS is shown in Fig. 11. The beamline or experimental station can use SSI listen only electronics or custom design interface to take absolute gap position.

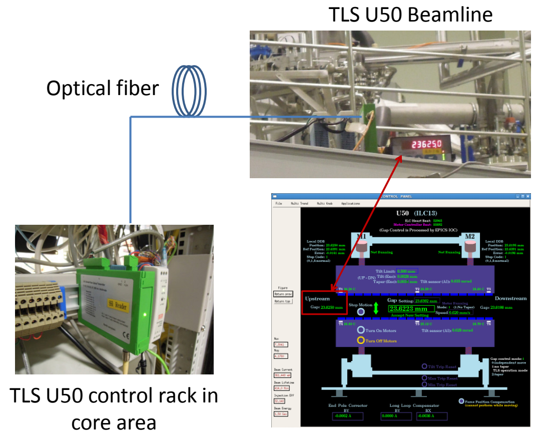


Figure 11: Gap value of U50 for on-the-fly experiments via directly send SSI encoder hardware signals through fibre link in TLS.

SUMMARY

TPS insertion devices controls are in implementation stage. First two sets of 2 meter long IU22 were delivered in June 2012. Preliminary test of control system for IU22 and EPU48 were done. Various EPICS supports and GUI were developed for IU22, EPU46 and EPU48. Deliveries of 3 meter long IU22/IUT22 by magnet group are in proceeding continuously. Controls integration of 3 meter long IU22/IUT22 maybe starts from the first quarter of 2014. Controls for all phase-I insertion devices are scheduled to finish at end of 2014.

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