CONTROL SYSTEM OF IN-VACUUM UNDULATOR IN TAIWAN PHOTON SOURCE

C. Y. Wu, C. Y. Liao, Jenny Chen, Y. S. Cheng, P. C. Chiu, K.T. Hsu
NSRRC, Hsinchu 30076, Taiwan

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, seven IU22s (In-Vacuum Undulator) will be planned, constructed, and installed. The control system for IU22 is based on the EPICS architecture. The main control components include the motor with encoder for gap adjustment, trimming power supply for corrector magnets, ion pumpers and BA gauges for vacuum system, temperature sensors for ID environmental monitoring and baking, and interlock system (limit switches, emergency button) for safety. The progress of IU22 control system will be summarized in this report.

INTRODUCTION

TPS is a 3rd generation light source which is based on advanced undulator technology to produce high brilliance synchrotron radiation. The TPS plans to install seven sets of IU (In-Vacuum Undulator) are arranged in five straight sections to fulfil various experimental requirements. Two IU22 which are 2 meter long have been delivered to NSRRC. The control system of IU22 is developed in NSRRC and used to commissioning two IU22s in the laboratory include gap motion, vacuum pressure and temperature reading/archiving for baking, interlock system, GUI development and so on. The parameters of IUs are shown in following table. Table 1 summary the kind of the IUs and its motors used [1].

Table 1: In-Vacuum Undulators Plan for TPS phase-I

Parameters	IU22	IU22	IUT22 (taper)
Photon Energy (keV)	5-20	5-20	5-20
Period (mm)	22	22	22
Nperiod	95	137	137
B_y (T)	0.79	0.79	0.79
$K_y$max	1.54	1.54	1.54
L (m)	2	3	3
Minimum Gap (mm)	3.5	5	5
Number of devices	2	4	**1**
Number of gap motors	1	1	2
Type of motor	Stepping motor	Servo motor	Servo motor
Main body vendor	Hitachi-Metals		
Controls	TPS standard insertion devices control environment (In-house)		

The main hard X-ray undulator source will be IU22 in TPS phase I. For IU22, encoder readings are fed directly to the motion controller. Semi-real time (approximate 5 msec) update of gap values in a remote location, i.e. at the location of monochromator controller or other beam line components.

Control system for all IU22 are done by NSRRC control team for economic reason, delivery a similar control environment is the goal. Two IU22 of TPS phase-I are shown in Fig. 1.

Figure 1: The two sets of 2 meter long IU22 in the laboratory.

HARDWARE ARCHITECTURE

All IUs will share the same control environments. The hardware devices of 2 meter long IU22 includes one stepping motor, two synchronous serial interface (SSI) rotary optical encoder, corrector magnet, two ion pumps, two BA gauges, thermal couples, minimum/maximum limit switches and emergency button. Control system of the IU22 is based on the standard TPS cPCI EPICS IOC. Motion controller is based upon Galil DMC-4040 series Ethernet based motion controller [2]. The controller is a full-featured 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 stepper motor of IU22 via stepper motor driver. The motion axes include two SSI rotary optical encoder connect to the motion controller directly. Motion axis accompany with limit switches for over travel protection.

The hardware configuration for TPS IU22 control is illustrated in Fig. 2. The system includes cPCI EPICS IOC, 128 bits DI/DO module, ADC/DAC IP (Industry Packs) modules, motion controller, ion pump and BA gauge interface, temperature monitoring solution and RS232/422/485 based device of the insertion devices frame. High precision low level power supply control for corrector magnet for feed forward look-up table. Current design includes the control interface for the beamline. Control rack layout of IU22 is shown in Fig. 3.

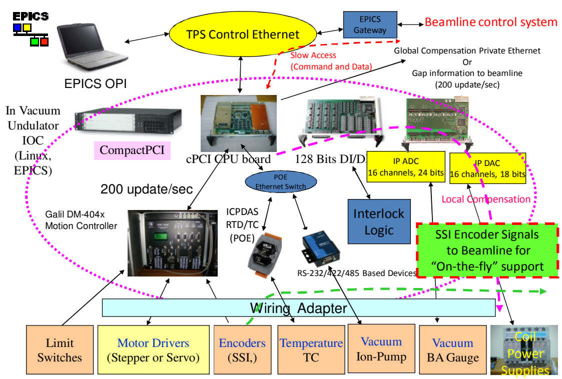

Figure 2: Basic hardware configuration for TPS in vacuum undulators in Phase-I.

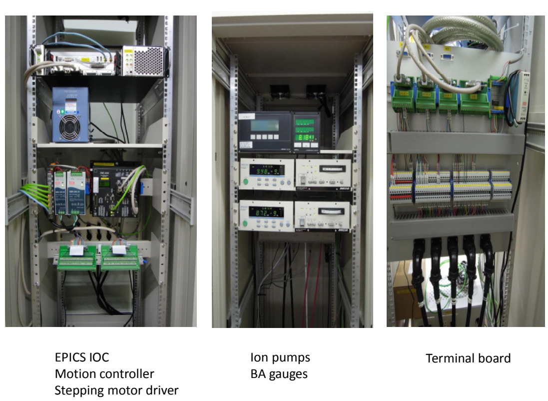

Figure 3: Control rack layout of IU22 for TPS.

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 scan of all position related process-variables (PV). The kernel driver, char device driver, is 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. 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. It includes software max/min limit checking; 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.

RESIDUE FILED 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 change could be tolerated. Local and global compensation schema for in vacuum undulator is illustrated in Fig. 4. Local compensation is performed by using lookup table to drive corrector magnets. 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. 5.

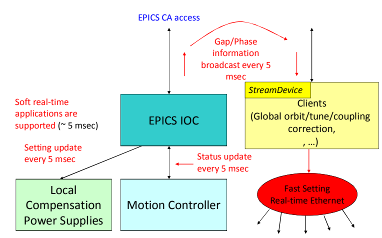

Figure 4: Local and global compensation schema for in vacuum undulator.

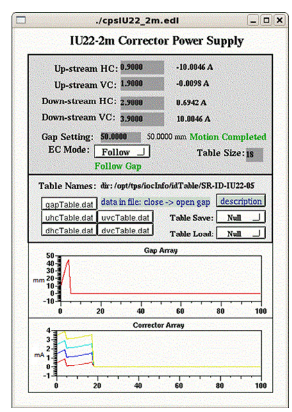

Figure 5: Local compensation prototype for IU22.

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 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.

ISBN 978-3-95450-122-9

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.

GRAPHICAL USER INTERFACE

The graphical user interface is implemented by using EPICS EDM and CSS (Control System Studio). The preliminary EDM page of IU22 is shown in Fig. 6. A main page with IU22 images is for general operation and maintain only page shows all status and adjustable PVs which are PID parameters, torque limit, speed … etc. Fig. 7 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. 8.

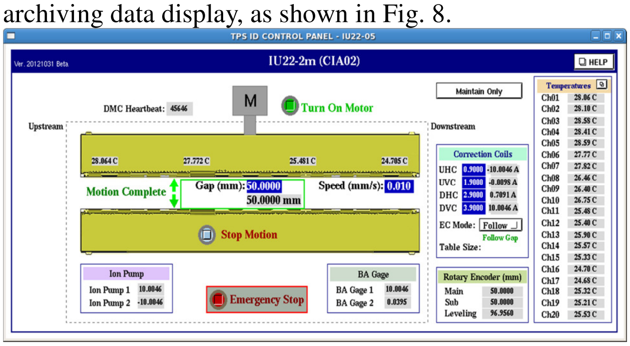

Figure 6: The preliminary GUI of IU22.

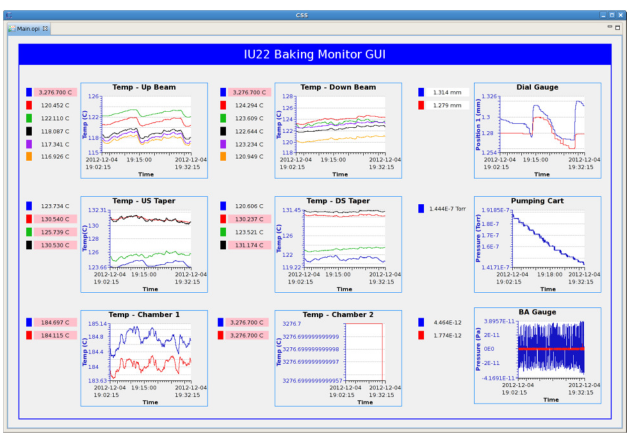

Figure 7: The preliminary baking monitor GUI of IU22.

Figure 8: Using Data Brower of CSS for IU22 baking archiving data display.

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 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 beamline monochromator energy scan are interesting recently to increase productivity and to meet requirement of scientific goals [4-5]. 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 IU22s for on-the-fly experiments via computer network access or directly send SSI encoder hardware signals through fibre link:

- Beamline or experiment station computer can read the gap position over the network through EPICS PV channel access (100 update/s or faster).
- 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). The beamline or experimental station can use SSI listen only module or custom design interface to take absolute gap position. Besides, SSI signal can be transformed to parallel 25 bits output in several different formats (Binary Code, or Gray code, BCD code) at beamline or experimental station.

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 was done. Various EPICS supports and GUI were developed. Deliveries of 3 meter long IU22/IUT22 by magnet group are in proceeding continue. Controls integration of 3 meter long IU22/IUT22 maybe starts from the third quarter of 2013. Controls for all phase-I insertion devices are scheduled to finish at end of 2014.

REFERENCES

[1] C. Hs. Chang, et al., “Progress in Insertion Devices for TPS in Phase I”, Proceedings of IPAC2011, San Sebastian, Span, September 2011.
[2] Galil motion control: http://www.galilmc.com
[3] Jenny Chen, “pciGeneral”, EPICS 2011 spring meeting. http://www.icg.nsrrc.org.tw/EPICS2011
[4] J. Krempasky, et al., “Synchronized Monochromator and Insertion Device Energy Scan at SLS”, Proceedings of the 10th International Conference on Synchrotron Radiation Instrumentation, AIP conference proceedings 1234, 705 (2010).
[5] T. Tanabe, et al., “NSLS-II Insertion Device Controls Plan“, Proceedings of ICALEPCS2009, Kobe, Japan, October 2009.