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CONTROL SYSTEM OF EPU48 IN TPS

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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, two EPU48s (Elliptically Polarized Undulator) will be installed. The control system for EPU48 is based on the EPICS architecture. All control functionality coordinate by the cPCI EPICS IOC. The main control components include the motor with encoder for gap adjustment and phase moving, trimming power supply for corrector magnets, temperature sensors for ID environmental monitoring , interlock system (limit switches, tilt sensor, emergency button) for safety and supporting of on-the-fly experiments for beamline. Features and benefits of EPU48 control system will be summarized in this 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 phase I beamline of TPS project [1-4].

Two EPU48 have been delivered to NSRRC. The control system of EPU48 is implemented and used to support filed measurement of two EPU48 in the field characterization laboratory. The control system of EPU48 is developed including gap/phase motion, protection system (hardware and software) and GUI development. Two EPU48 of TPS phase-I beamline project are shown in Fig. 1.

Figure 1: Two EPU48s of TPS phase-I beamline project.

The EPU48 consists of six axes servo motor. Two servo motors control the gap, one on the upstream girder and one on the downstream girder. The other four servo motors control the phase, two on the upper girder inner and outer and two on the lower girder inner and outer. Each axis servo motor employs a rotary absolute encoder. In additional, each servo axis is tracked with a TR absolute linear encoder with 0.1 μm resolution. The linear encoder provides direct gap position sensing and frame reference to eliminate the effects of backlash. The EPICS IOC performs a software tilt calculation based on the feedback linear encoders not only from the tilt sensors. With gap / phase change, the corrector magnets for IDs require very intricate power supply controls to maintain the very stringent beam stability requirements.

DRIVER SYSTEM

Gap/Phase Driver Mechanism

The servo motor that controls EPU48 gap and phase could be operated at about 63.3 revolutions per second. The EPU48 gap width is equipped with 10-mm pitch screws and 1000:1 gear ration to drive the back beam (see Fig. 2). One motor revolution is corresponding to 20 μm gap change. The EPU48 phase movement is equipped with 10-mm pitch screws and 100:1 gear ratio to drive the slide beam (see Fig. 3). The resolution is 100 μm per revolution [5].

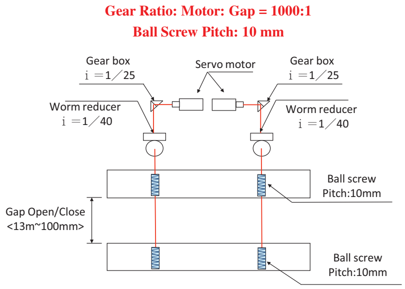


Figure 2: Gap driver mechanism of EPU48.

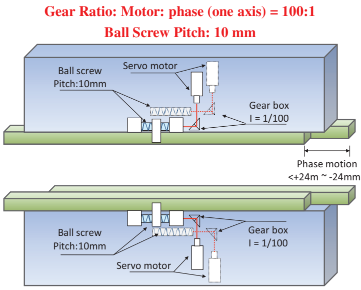


Figure 3: Phase driver mechanism of EPU48.

Motors and Motor Drivers

Six Parker AC servo motors, MPP1154B6S-NPSBV, are used for driving gap and phase motion. The motor equips with Sick-Stegmann SRM50 Hyperface Sin/Cos encoder. The servo motor driver, Parker Hannifin Compax3 S150 and configured to torque mode. The interconnection between motion controllers and Compax3 drivers is performed by an adopted board.

DESIGN OF EPU48 CONTROL SYSTEM

The control related devices on the body of the EPU48 include all servo motors, Serial Synchronous Interface (SSI) encoders, tilt sensors, long coils, limit switches and emergency buttons. The control for the EPU48 is based on the standard TPS cPCI EPICS IOC. The hardware configuration of EPU48 control is shown in Fig. 4.

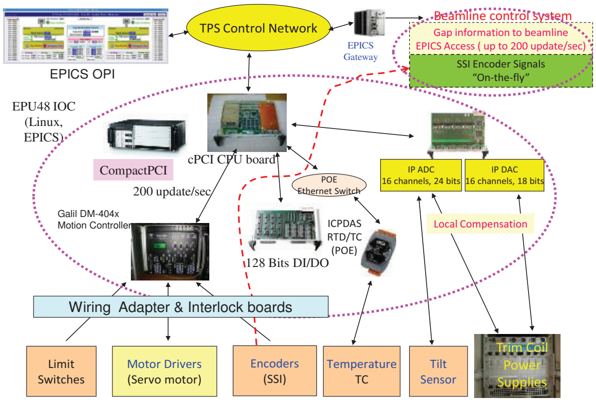
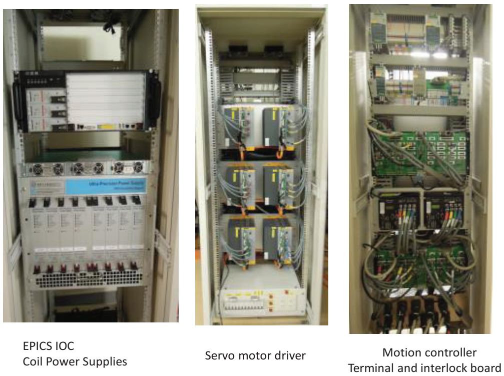


Figure 4: The hardware configuration of EPU48.

There are several cards installed in a cPCI crate: CPU board, DI, DO, AI and AO cards, as the EPU48 EPICS IOC. The motion controllers are connected to the EPICS IOC via Ethernet directly. Control rack layout of EPU48 is shown in Fig. 5.


EPICS IOC
Coil Power Supplies

Servo motor driver

Motion controller
Terminal and interlock board

Figure 5: Control rack layout of EPU48.

CONTROL SYSTEM HARDWARE

cPCI Crate

The hardware of the cPCI crate controller is composed of a CPU board running Fedora, one analog-to-digital interface card with 24 bits resolution and one digital-to-analog interface card with 18 bits resolution for trim power supplies control and tilt sensors readings, a digital input card for status monitor and a digital output to reset the motor controller. The EPICS IOC running on the cPCI crate provides remote control requests and higher level applications.

Motion Controllers

The Galil DMC-4040 Ethernet based controller is chosen for the gap and phase control [6-7]. Two DMC-4040 motion controllers control gap and phase of the EPU48 individually. The DMC-4040 is a stand-alone controller equipped with four axes motion control with SSI encoder feedback capability. The close loop control is essential for the gap/phase motion control because of the magnetic force effect. The servo torque demand signal is connected via an adopter to the Compax3 motor driver.

Tilt Meters

To provide tilt protection, two high precision tilt meters with micro-radian resolution were mounted to the upper and lower support beams. The output of the both tilt sensors connected to the ADC card of the EPICS IOC for alternative tilt read back and preliminary tilt protection.

Trim Power Supplies

The correction coils are powered by standard switching power supplies which are the same as for the TPS storage ring correctors. They are controlled via the DAC card installed in the cPCI crate.

Protection

There are three levels of protection mechanism implemented including interlock board, motion controller and EPICS IOC. All protection devices will be split into several isolated outputs to hardwired logic, motion controller, and EPICS IOC to guarantee no single point of failure occurred.

Several safety protections are performed by the motion controller as the first level, which are over travel limit switches, torque limits, stall, encoder fault and close-loop position error limit. Limit threshold check of encoder read-back is done by EPICS IOC db-scan. According to the encoder values, upper or lower beam tilt limit may also be monitored by the EPICS IOC. The two software limit checking is performed at every 5ms as the second level protection.

The third level protection is the interlock boards which provide a redundant and advanced protection of the structure from failures. A major feature of this protection mechanism is that operates independently of the motion control system.

The interlock board has the following inputs:

- Forward and reverse limit switches for all six axes.
- Chamber switches (protection chamber) for four vertical axes.
- Emergency push-buttons.

The interlock board can halt the motion of any axis by disabling the given motor driver within a few milliseconds. The trip state can only be reenergized if all of the errors are cleared or overridden.

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OPERATOR INTERFACE

The graphical user interface (GUI) is implemented by using EPICS EDM and CSS (Control System Studio). Fig. 6 has shown the preliminary main page of EPU48. The left page is for general operation and the right page shows all status and adjustable PVs which are PID parameters, torque limit, speed and so on that is for maintenance only.

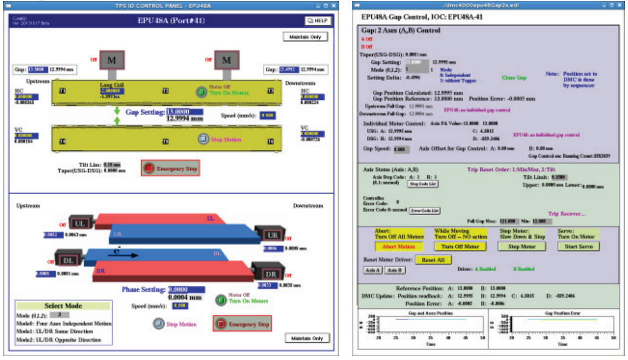
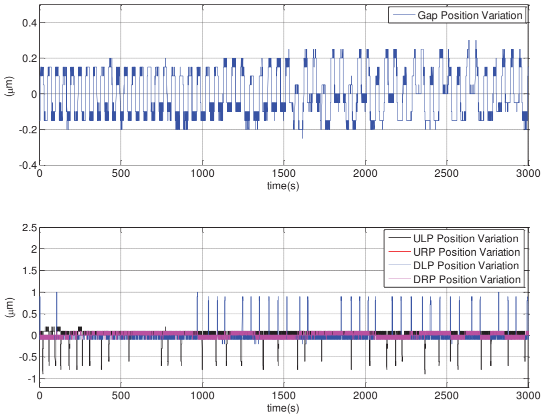


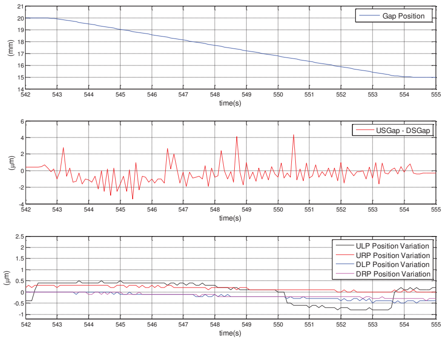
Figure 6: Operation GUI of EPU48.

PERFORMANCE ISSUES

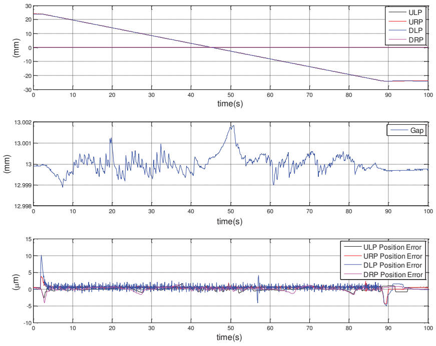
There are several control performance issues about EPU48 such as gap or phase resolution, reproducibility and two axes tracking. For the EPU48, the output signals from motion controller to motor drivers are analog signals corresponding to the position error. The proportional, integral and derivative parameters of the feedback position control need to be optimized. Various motion conditions have been tested. The gap reproducibility of EPU48 is ±0.3 μm and the phase reproducibility is ±1 μm (shown in Figure 7 (a)). Figure 7 (b) reveals the gap motion profile for 0.8 mm/sec motion. Two gap axes have been measured simultaneously during motion from a 20 mm to 13 mm gap. The relative gap difference never exceeds ±4 μm and position variation of four phase axes is less than ±1 μm. The gap variation is ±2 μm while two phase axes (DLP, URP) motion in 0.5 mm/sec from 24 mm to -24 mm is shown in Fig. 7 (c).



(a) Gap and phase reproducibility measurement



(b) gap movement



(c) Two phase axes movement

Figure 7: Motion profile of gap and phase.

CURRENT STATUS

Basic functionalities of the EPU48 control system were implemented and tested. Optimize the motion control performance were done. Various EPICS supports and GUI were developed for EPU48. The two EPU48 are scheduled to install at TPS straight section in 2015 to do preliminary test accompany with beam commissioning of the TPS storage ring.

REFERENCES

[1] C. Hs. Chang, et al., "Progress in Insertion Devices for TPS in Phase I", Proceedings of IPAC2011, September 2011, San Sebastian, Spain.

[2] C. Y. Wu, et al., "Insertion devices control plans for the Taiwan Photon Source", Proceedings of IPAC2012, May 2012, New Orleans, Louisiana, USA.

[3] C. Y. Wu, et al., "Control System of In-vacuum Undulator in Taiwan Photon Source", Proceedings of IPAC2013, May 2013, Shanghai, China.

[4] C. Y. Wu, et al., "Status of the TPS Insertion Devices Controls", Proceedings of ICALEPCS 2013, October 2013, San Francisco, USA.

[5] C. Hs. Chang, et al., "Design and development of an elliptically polarized undulator of length 3.5 m for TPS", Proceedings of IPAC2010, May 2010, Kyoto, Japan.

[6] Galil motion control: http://www.galilmc.com

[7] Jenny Chen, "pciGeneral", EPICS 2011 spring meeting, http://www.icg.nsrrc.org.tw/EPICS2011