MT 26
International Conference
on Magnet Technology
Vancouver, Canada | 2019

Wed-Af-Po3.16-02[20]

Design and Development of a New Control Architecture for Elliptically Polarizing Undulator at Taiwan Photon Source

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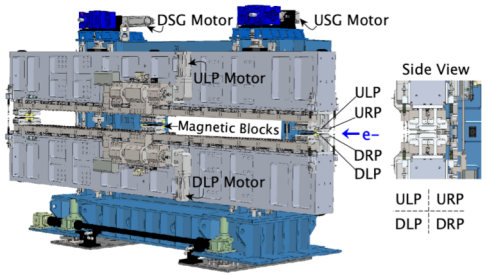
Abstract

During the phase-II beamline project at the Taiwan Photon Source (TPS), elliptically polarized undulators (EPU), called EPU66 and EPU168, will be installed in 2020. The new control system for the EPUs is based on the Experimental Physics and Industrial Control System (EPICS) and Ethernet Control Automation Technology (EtherCAT) framework. The EPU control elements include: motors with absolute optical encoders for gap and phase control, corrector magnets power supply control for trim coils, interlock safety systems to automatically stop motion based on encoder readings, limit switches, tilt sensors and emergency buttons. All control functionalities are coordinated by a fan-less embedded computer with three Ethernet ports. User interface for operators and beamline users are included to support the operation of the system, such as gap/phase control. Reliable operation of the EPU is important to users of beamlines. The most unpredictable fault is due to a soft error in the absolute optical encoders. There are several protection solutions to avoid faults, e.g. by increasing the distance of the encoder from the beam center, by a lead shield cover and finally by adopting an auxiliary position sensing device to cross check the position and perform the necessary procedure. Efforts to improve operational reliability of the EPU controls will be discussed. Features and benefits of the EPU66 and EPU168 control system will be summarized in this report.

Introduction

- The EPU66 and EPU168 are permanent magnet-based ID, requiring six motors, to adjust in a coordinated way gap and phase positions.
- The control system architecture for the EPU66 and EPU168 is based on the EPICS and the EtherCAT framework is used.
- The EPU66 and EPU168 have the same body design, but different parameters.

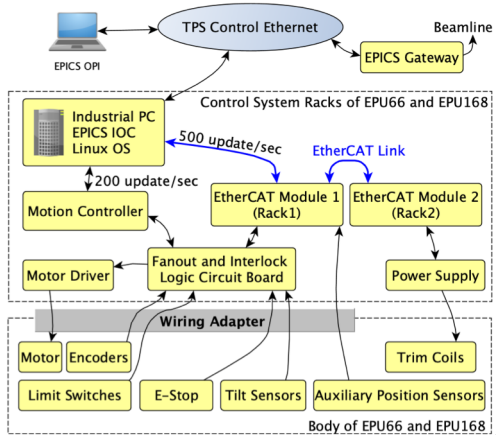


SPECIFICATIONS OF EPU66 AND EPU168 UNDULATOR FOR TPS

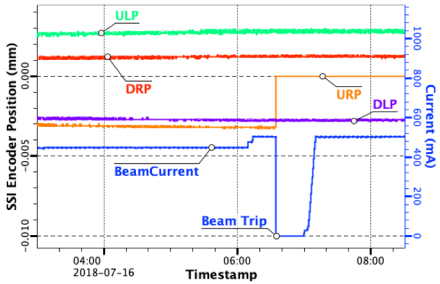
Items	EPU66	E168
Photon energy / keV	0.085-2.5 (HP)	>0.015 (HP)
	0.15-2.5 (VP)	>0.07 (VP)
Period / mm	66	168
Number of periods	62	24
Magnetic field / Tesla	0.87 (By)	0.52 (By)
	0.64 (Bx)	0.23 (Bx)
Magnet material	NdFeB	
Min. magnetic gap / mm	16.8	28
Operating temperature / K	295	

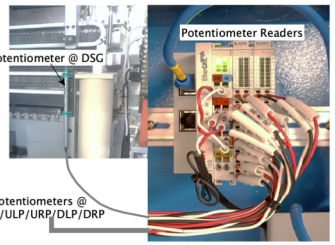
Control System Design

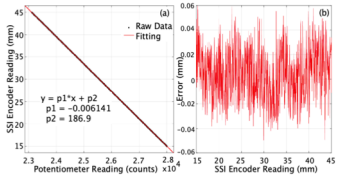
- The control-relate components of the EPU66 and EPU168 include: Linux-based computer, user operation interface, servo motors control, serial-synchronous-interface (SSI) optical encoders, limit switches, tilt sensors, auxiliary position sensors, power supply and trim coils, interlock safety system and emergency buttons.
- There are many EtherCAT-based modules used for construction of EPU control system, the modules of ADC and DAC for power-supply control and tilt-sensor readings, digital input module for the status monitor, and digital output module to reset the motor controller. Also the potentiometer modules are used for the auxiliary position sensors reading.
- Three levels of basic protection are implemented with the motion controller, EPICS IOC, and interlock logic board.
- All protection devices signal (such as limit switch and E-Stop) are split into three isolated outputs via fan-out circuit to the interlock logic board, motion controller and EPICS IOC (through EtherCAT digital input module) to ensure that no single point of failure exists.

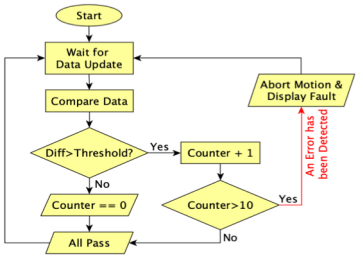


Detect and Recover Encoder Errors





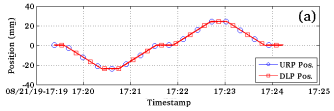




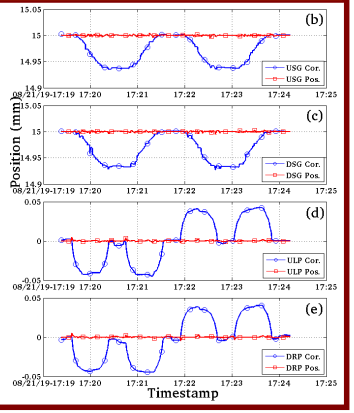
- There is a chance of a soft error in the optical encoder when the beam trip event occurs due to the excessive radiation dose.
- The method of detect the encoder soft error is to adopt auxiliary position sensing devices to simultaneously monitor the position.
- Potentiometers are installed to mirror the absolute encoders on the IDs to provide a simple but robust gap and phase measurement for the protector system even if the motion control encoders fail.
- All potentiometers need to be calibrated with the encoder and to generate a formula to convert the voltage counts to an absolute position value. After that, the error of the auxiliary potentiometer absolute position compared with SSI encoder can be controlled at approximately 0.1mm during long distance tracking. This is enough for crosscheck the absolute SSI encoder health for malfunction protection purpose.
- A protection process is developed to compare the position from SSI encoder and potentiometer, if the difference is large then 1mm (configurable) and occurs continuously more than 10 times, the abort motion command will be sent to the motion controller to stop the motor driver within a few milliseconds.
- When the SSI optical encoder has a soft error, the operator can perform a recovery process. This process is done by a Linux shell script, which controls several EPICS PVs (Process Variables) to perform, including: power off, wait a while, power on, and check encoder status.

Motion Behavior Evaluation

- In order to evaluate the feedback motion behavior under the action of magnetic force, the control system newly added the function of recording the motor driver output position signal.



- This position signal is the motor encoder signal, which can fully represent the true motion output process of the motor. This idea has been installed and tested on the existing EPU48 and EPU46.
- (a), no change in the gap position can be observed, but the encoders of the two gap motors are corrected by about 50 micron,
- (b) and (c). The amount of variation in the gap axis is caused by the magnetic force generated by the phase movement. The same condition can be observed in the other two phases (ULP and DRP),
- (d) and (e). Through this function, the motor's movement status can be recorded, and the health diagnosis and protection of the moving parts (motor and mechanical equipment) can be development in future to reduce malfunctions.



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