NEW CONTROL SYSTEM FOR THE EPU4.6

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Abstract

The Elliptically Polarized Undulator 4.6 (EPU4.6) for the Taiwan Light Source (TLS) was contracted to the vendor in late 2004. Due to various reasons in vendor side, the system was not delivered with full functionalities on time. The contract was terminated and the vendor agreed to deliver it to NSRRC in January 2009 after long negotiation. After intensive examination had been processed, revamp was started from March include mechanical and control system. Due to proprietary design of the vendor and lack of required technical documents of the existed motion control system, abandon these devices and replace the original design with another open solution is the most difficult decision. New control system implementation for the EPU4.6 was done recently. This project is not only to rebuild the entire control system but also to meet the original specifications. Features and benefits of the new control system of EPU4.6 will be summarized in this report.

INTRODUCTION

The EPU4.6 was contracted to the ADC as a turn-key system in late 2004 [1,2]. The original design consists of an Allen Bradley (AB) ControlLogix PLC and an eight axes Kinetix 6000 servo controller (SERCOS compatible). Four servo motors control the gap, two on the upper girder and two on the lower 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 and is capable of up to 790,000 counts per rev with 4096 revs in total. 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 PLC performs a software tilt calculation based on the feedback linear encoders not only from the tilt sensors. Host communication is via Ethernet, but a touch panel is provided for local display of gap, status, and errors with security protected control screens for maintenance and debug. However, the incomplete system was delivered after the contract terminated. To save these expensive devices, a re-engineering project of the control system for EPU4.6 was launched. Several weeks' fruitless efforts explore the low possibility to continue unfinished work; the decision of abandoning the original system was done. A lack of detail technical information and complex design are the major reasons to make the decision. A Simpler and straightforward design is replaced. Before making the decision, the schedule, manpower, expertise of current staffs and further requirements were evaluated.

APPROACH FOR THE EPU4.6 NEW CONTROL SYSTEM

Several detailed analysis of the control related devices on the body of the EPU4.6 include all servo motors, Serial Synchronous Interface (SSI) encoders, tilt sensors and limit switches were done. The original SERCOS compatible motor drivers are replaced by Parker Hannifin Compax3 S150 driver because of the compatibility with the existed AB servo motors with Hyperface Sin/Cos encoder. The Galil Ethernet based motion controller is adopted due to it is compatible with the motion controller in VME form factor which was used in the U9 and the EPU5.6 project [3,4], they were installed at TLS in late 1990s and also satisfy the future requirements for the new project, TPS (3 GeV synchrotron light source, Taiwan Photon Source).

There are several cards installed in a VME crate: CPU board, DI, DO, AI and AO cards, as the EPU4.6 controller. The motion controllers are connected to the VME system via Ethernet directly. The power supplies of correction coils are MCOR30 system manufactured by BiRa Systems. A dedicated PLC for interlock protection takes input from limit switches, kill switches, tilt sensors and emergency button from the driver system. Before the interlock condition removed or reset, the PLC logic will restrict motion if any limit sensor activates.

The picture of the EPU4.6 is shown in Fig. 1(a). New control system rack is shown in Fig. 1(b).

(a) EPU4.6.　　　　　　(b) New control rack.
Figure 1: Photograph of the EPU4.6 and new control rack.

The new control system has the following advantages compared with the old one:
- Full functionality.
- Updated motion control hardware and software.
- Simple design.
- Common expertise for EPU4.6 project, the existed insertion devices of TLS and future TPS requirements.

EPU4.6 NEW CONTROL SYSTEM HARDWARE

VME Crate

The hardware of the VME crate controller is composed of a CPU board running LynxOS, one analog-to-digital interface card and one digital-to-analog interface card for trim power supplies control and tilt sensors readings, a digital input card for status monitoring and a digital output to reset the motor controller. The control software running on the VME system provides remote control requests and higher level processing.

Motors and Motor Drivers

Eight Allen-Brandy AC servo motors, MPL-A4530K-MK24AA, are used for driving gap and phase motion. The motor equips with Sick-Stegmann SRM50-FFA0-S01 Hyperface Sin/Cos encoder. The servo motor driver, Parker Hannifin Compax3 S150, is compatible with the AB servo motor, and configured to torque mode. The interconnection between motion controllers and Compax3 drivers is performed by an adopted board.

Motion Controllers

The Galil DMC-4040 Ethernet based controller is chosen for the gap and phase control. Two DMC-4040 motion controllers control gap and phase of the EPU4.6 individually. The DMC-4040 is a stand-alone controller equipped with four axes motion control with SSI encoder feedback capability. To get better performance, each axis keeps a set of PID (proportional, integral and derivative) parameters and the servo loop is processed at every 0.5 milliseconds. It is essential for the phase motion control because of the magnetic force effect. The servo torque demand signal is connected via an adopter to the Compax3 motor driver.

There are 3 motion modes available for the gap control: individual axis, taper and full gap control. For the phase motion control, there are individual phase arm move, coordinate phase arms move.

Encoders

Eight TR Electronic TR-140S SSI absolute encoders are used to accompany eight servo motor driving mechanism. The motor controllers equip SSI interface to communicate with the encoders. The encoder can be programmed the parameters like preset value, polarity...etc via RS485 interface.

Tilt Sensors

To provide further protection, two ADI's Tuff Tilt 420 high precision tilt sensors 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 VME for alternative tilt read back and preliminary tilt protection. Both outputs are also fed into analog input module of PLC for interlock level checking.

Trim Power Supplies

The correction coils are powered by standard switching power supplies which are the same as for the TLS correctors. They are controlled via the DAC interface card installed in the VME crate.

Interlock

Various protection mechanism are performed by motion controller includes over travel limit switches, torque limits, motor over temperature, encoder fault, position error limit. This is done at very servo loop. Current servo rate is set to 0.5 milliseconds which is fast enough to satisfy these fast interlock requirements.

The encoders reading are used to provide a second level of limit thresholds checking. The encoder values are also used to calculate precise beam tilt. This is done by the VME host processor at every 5 millisecond. The feed forward compensation of the magnet field that drives the correction coils will be done at the same rate.

A PLC based protection system has been developed to provide a redundant and advanced protection of the structure from failures. A key feature of this protection mechanism is that operates independently of the motion control system.

The PLC has the following inputs:

- Forward and reverse limit switches for all eight axes.
- Eight kill switches (protection chamber) for four vertical axes.
- Tilt sensors mounted to the upper and lower support beams.

The PLC can halt the motion of any axis by disabling the given motor driver within a few milliseconds. The PLC can stop any axis anytime even the entire system. The trip state can only be reenergized if all of the errors are cleared or overridden. The protection PLC generates a set of composite event signals for the control system. The physical limit switch inputs are passed directly through to the motion controller. The motion state changes to "motor off" while limit switch is active. The tilt sensors are also processed which are compared against thresholds, to give an independent tilt figure.

EPU4.6 NEW CONTROL SYSTEM SOFTWARE

Software Structure

The software structure of the EPU4.6 follows the framework of the TLS control system as shown in Fig. 2. There are many processes working in multi-thread manner. All motion control related parameters are updated at rate of 200 Hz from the motion controller to the VME. While the data is updated to the TLS console level computers at rate of 10 Hz. The setting process will serves setting requests from console computers on-demand.
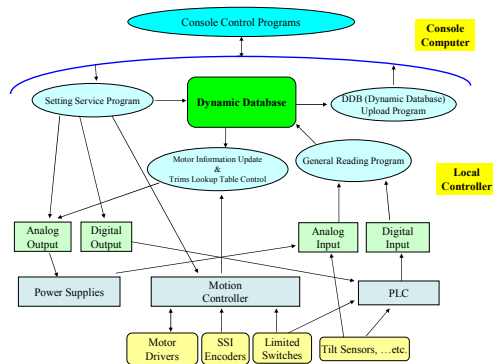
Figure 2: EPU4.6 control software structure.

Motion Data Update

The DMC-40x0 creates a record and sends it to the VME periodically via a UDP/IP Ethernet handler. Furthermore, it provides up to 8 Ethernet handlers for various application programs. Therefore, the update rate of the motor controller information (such as encoder, motor status…etc) can achieve few hundred Hz. For the feed forward field compensation loop by driving the coils can be done at 200 Hz. This is important to reduce the effect to the stored beam when the insertion moves.

Operator Interface

The graphical user interface (GUI) is installed on Linux PCs as the control consoles. Operation pages include the setting and reading of the gap and phase positions, trim power supplies, the status monitoring of the tilt sensors, limit switches, kill switches, motion controllers, motor drivers and residual field compensation mechanism selection. For the critical functions such as errors recovery, reset motion controllers, motors servo/stop function and reload the residual field compensation table are hidden in another page for maintenance purpose. Figure 3 illustrates the gap and phase control pages.
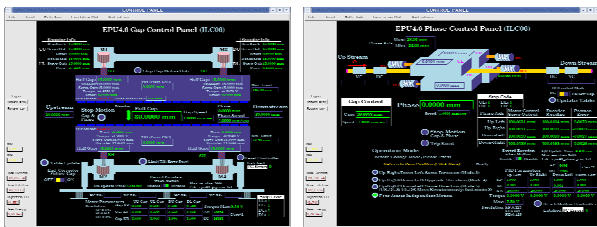

Figure 3: Operation GUI of EPU4.6.

Feed-Forward Table Management

The trim coils compensation scheme with feed-forward table will be used to compensate the imperfection of the EPU4.6. It is expected that a few tenth of micron in RMS orbit displacement can be achieved. The tables will be obtained during the insertion device commissioning stage. However, fast orbit feedback system provides further orbit stability improvement during the gap/phase change of the EPU4.6 operation.

PERFORMANCE

Various motion conditions have been tested. Soomth motion can be achieved despite the mechanical structure still in refurbishment in driven mechanism. Figure 4 (a) reveals the gap motion profile for 3 mm/s motion. The encoders recorded simultaneously while phase motion in 8 mm/s is shown in Fig. 4 (b). The positioning performance in gap and phase seems not good enough due to the bad design in mechanical system, reasons of the shortage combine large backlash, less rigidity of the fixture of the driven mechanism, and modification is under way.
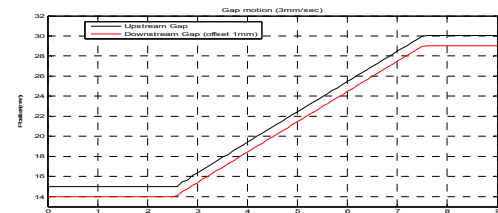
(a) Gap movement
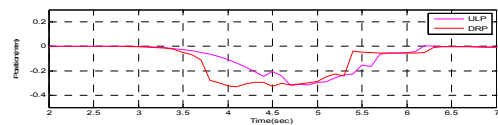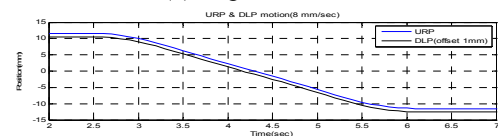
(b) Phase movement

Figure 4: Motion profile of gap and phase.

CURRENT STATUS

Basic functionalities of the EPU4.6 new control system were implemented and tested. Optimize the motion control performance, enhance functionality, improve engineering and reliability of the EPU4.6 control system are underway accompanied with the mechanical improvement which are expected to be done before the end of 2009.

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