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THE DEVELOPMENT AND APPLICATION OF MOTION CONTROL SYSTEM FOR HEPS BEAMLINE

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Abstract

In synchrotron radiation facilities such as the High Energy Photon Source (HEPS) beamline, thousands of motorized actuators are equipped on different optical devices, such as K-B mirrors, monochromator and transfocators, in order to acquire the specified properties of X-ray. The motion control system, as a part of the ultra-precision mechatronics devices, is used to precision positioning control, which not only has ability to realize basic motion functions but also can handle complex motion control requirements. HEPS has developed a standardized motion control system (MCS) for synchrotron radiation applications. In this paper, the structure of hardware and software of MCS will be presented, and some applications are demonstrated in detail.

INTRODUCTION

In the 15 beamlines of HEPS Phase I [1], there are thousands of actuators that required to control, including of PMSM, VCM, piezo and stepper motors. The number of stepper motors accounts for approximately 90 percent due to its high resolution ability, including two phase stepper and five phase stepper.

In order to satisfy the torque and size requirements of the optical devices, different motors must be employed, which demand that the MCS has the flexibility in configuring the driver current and micro-step. The position encoders were utilized in some motion axes for the application of close-loop to achieve the high repeatability. Therefore the MCS must be capable of supporting the different sensors, such as AqB, Biss-C and Endat2.2. Meanwhile, MCS should support the various types of limit switches, brakers and so on, to protect the mechanics devices. It is necessary to establish a uniform electrical standard, such as the connection between controller and devices (e.g. motor, encoder), the interface between controller and driver. In the aspect of field deployment, the large distances between controller and motors should be guaranteed. Besides the fundamental motion control requirements mentioned above, the complex devices in the end station of beamline especially, introduces more demanding performance criteria for MCS, include of synchronisation of multiple axis motions, complex trajectory planning, and real-time position event trigger.

Considering of the personnel resources and development costs, it's a significant challenge to satisfy all the control requirements of motion axes through a unified motion control system. It is very popular to use the VME controller in the majority of synchrotron labs worldwide, such as CLS [2], BESSY [3], and SSRF [4]. But the VxWork OS is so expensive, HEPS give up this scheme. From the perspective of HEPS and with reference to the other synchrotron labs, we have developed a novel motion control system utilizing commercial products.

In this paper, we will introduce the hardware structure of motion control system in detail. The software was developed under the Experimental Physics and Industrial Control System (EPICS) control framework [5]. Finally, several applications of MCS were demonstrated.

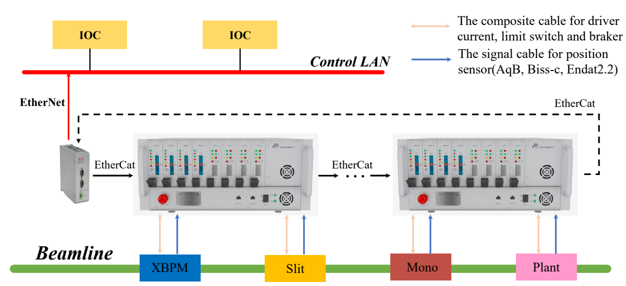

Figure 1: The overall hardware architecture of HEPS MCS.

THE ARCHITECTURE OF MOTION CONTROL SYSTEM

System Overview

The MCS is built of three main hardware components: master controller, control rack and driver board, the hardware architecture as shown in Fig. 1. A single MCS can support up to 64 axis, according to the EtherCAT fieldbus.

Figure 2: The control rack of MCS.

The MCS as the distributed system separates the control unit and driver unit. The master controller and control rack belong to the control unit. The controllers of ACS products (SPiiPlusEC and PDIcl) are the core of control unit where

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SPiiPlusEC is the master controller and PDIcl is the slave module, which are connected through EtherCAT fieldbus. The driver unit includes two-phase driver and five-phase driver, both of which are composed of core driver module (e.g. Phytron, Melec and oriental motor) and interface board. And the interface boards have been developed for different driver module, which make the driver unit have uniform electrical interface.

The Structure of Control Rack

The size of control rack is 3.5U 19-inch as shown in Fig. 2. In the front panel,there are two RJ45 interfaces for EtherCAT fieldbus, a emergency stop switch, several power supply leds and a drvier supply button. The eight slots of rack are used to install the driver board. To ensure system reliability, the back panel is equipped with standard connectors for motors, encoders and digital I/O.

Figure 3: The internal structure of control rack

A control rack contains PDIcl (slave module of EtherCAT), motherboard, the power supply for controller and driver. The detail of inside structure of control rack is demonstrated in Fig. 3. PDIcl as slave controller was used to acquire the I/O signal and send control signals to motherboard. The motherboard is a core component of control rack, which transforms the signal level and distributes signals to corresponding channels. The different types of driver units are compatible with all motherboard channels.

The way of processing of signal inside the control rack is displayed in the Fig. 4. Except of the encoder, digital I/O and braker devices be directly controlled by PDIcl, all of signals have been processed though the motherboard. All of input and output signals between the motherboard with the driver unit and PDIcl are optically isolated.

The Driver Unit

As is mentioned above, the driver unit consist of driver module and interface board. For convenience, we have already developed different interface boards to suit for different driver modules, all of which have same functions. The characteristics of driver module are shown in Table 1.

The driver current and micro-step can be configured though the DIP switch in the driver module. The interface

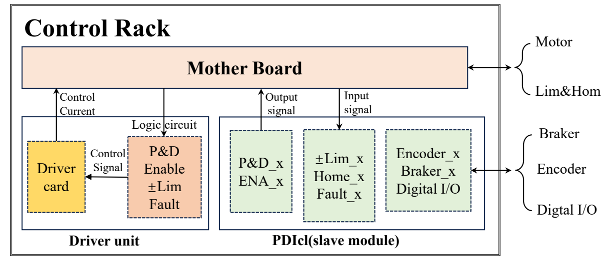

Figure 4: The way of processing of signal inside the control rack.

Table 1: The Type of Driver Module of MCS

Driver unit	SMD2	SMD514	SMD524
Driver type	Two phase	Five phase	Five phase
Core module	ZMX+	GDB-5F40	CVD524BK
Motor current	0.12-6 A	0.3-1.35 A	0.6-2.4 A
Micro-step	1-512	1-800	1-250

board provides flexible configuration capabilities for adjusting the effectiveness of limit switch, direction signal and remote enable signal. The true control signals that are finally sent to driver module have been processed by the logic protected circuits based on the state of limit, error and enable signals. In the front panel of driver board, several leds are utilized to indicate the status of axis.

THE APPLICATION

In practice, we make use of the EPICS control system as the highest level applications to provide process variable (PV) interface. The IOC of MCS [6] has been developed based on the the asynMotor (Model3) framework [7]. All of properties of motion axis have been realized by standard motor record, which provides the user with basic motion control functions. In the experiment, users of beamline are accustomed to controlling the properties of x-ray directly, instead of the motion axis, such as adjusting the hole of slit to change the size of X-ray beam and manipulating the Bragg angle to modify the energy of monochromatic light. Combing the motor record and other EPICS record can realize the complex control function by the channel access (CA) protocol of EPICS.

The white beam mirror (WBM) of BE has five degrees of freedom needed to be adjusted, which not directly driven by the motor. The motion of yaw is achieved though the motor driving the compliant mechanism, and the adjustment of height and pitch of WBM are accomplished by synchronized motion of two axes. In this situation, the combination the soft channel of motor record and the transform record not only can realize the conversion of coordinates, but also can decouple the relationship of motion axis. The control logic of the freedom of height and pitch is illustrated in the Fig. 5.

Firstly, the height and pitch are defined as pseudo motors though soft channel of motor record, whose command will be processed into the true motion command of motion axes by the transform record. The readback of motion axes are also handled by the other transform record, and the calcula-

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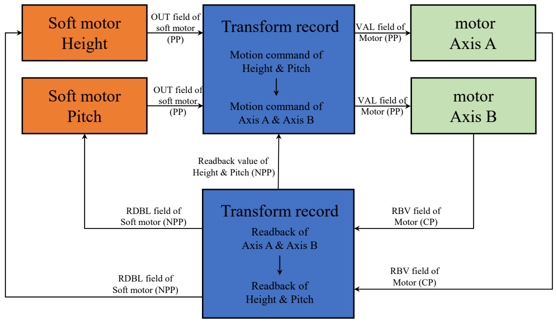

Figure 5: The control logic of whit beam mirror

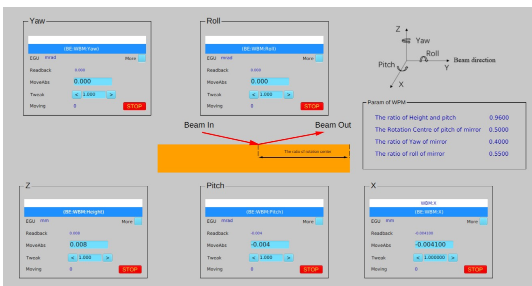

Figure 6: The OPI of white beam mirror

tion results will be respectively transmitted to pseudo-motor record and transform record in different ways. The WBM GUI is developed by CSS (Pheobus), as shown in Fig. 6. By this method, users not only can directly control the DOF of the WBM to deflect the X-ray, but also can independently control the position of motion axes, thus achieving the decoupling between pseudo motor and true motion axes.

CONCLUSION

The paper proposes a novel motion control system for HEPS beamline. The hardware structure of MCS has been described in detail. The design of the modular structure and the unification of standard interface allows to provide the best solution for each mechatronics device during the design and installation. The application of MCS for the white beam mirror demonstrate its feasibility and effectiveness. In the future, we will gradually complete the installation of MCS in HEPS, and novel EtherCAT-based systems will be developed to support the servo motor and piezo-actuators.

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