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Design of Control Instrumentation of a 4 meter variable polarization undulator (EPU)

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Abstract. The design of a high end, very sophisticated controller, that consists of an Allen Bradley ControlLogix PLC with a Kinetix servo controller for a 4.16 m EPU is presented. Four servo motors control the gap - 2 on the upper girder and 2 on the lower girder, and another 4 servos controls the phase - 2 on the upper girder inner and outer and 2 on the lower girder, inner and outer. This system is designed for The Taiwan Light Source (TLS) a synchrotron radiation machine of the National Synchrotron Radiation Research Center (NSRRC) at the energy of 1.5 GeV with electron beam current of 200 ~ 400 mA.

Keywords: Undulators, Insertion Devices, Control Instrumentation, EPU, Allen Bradley ControlLogix PLC
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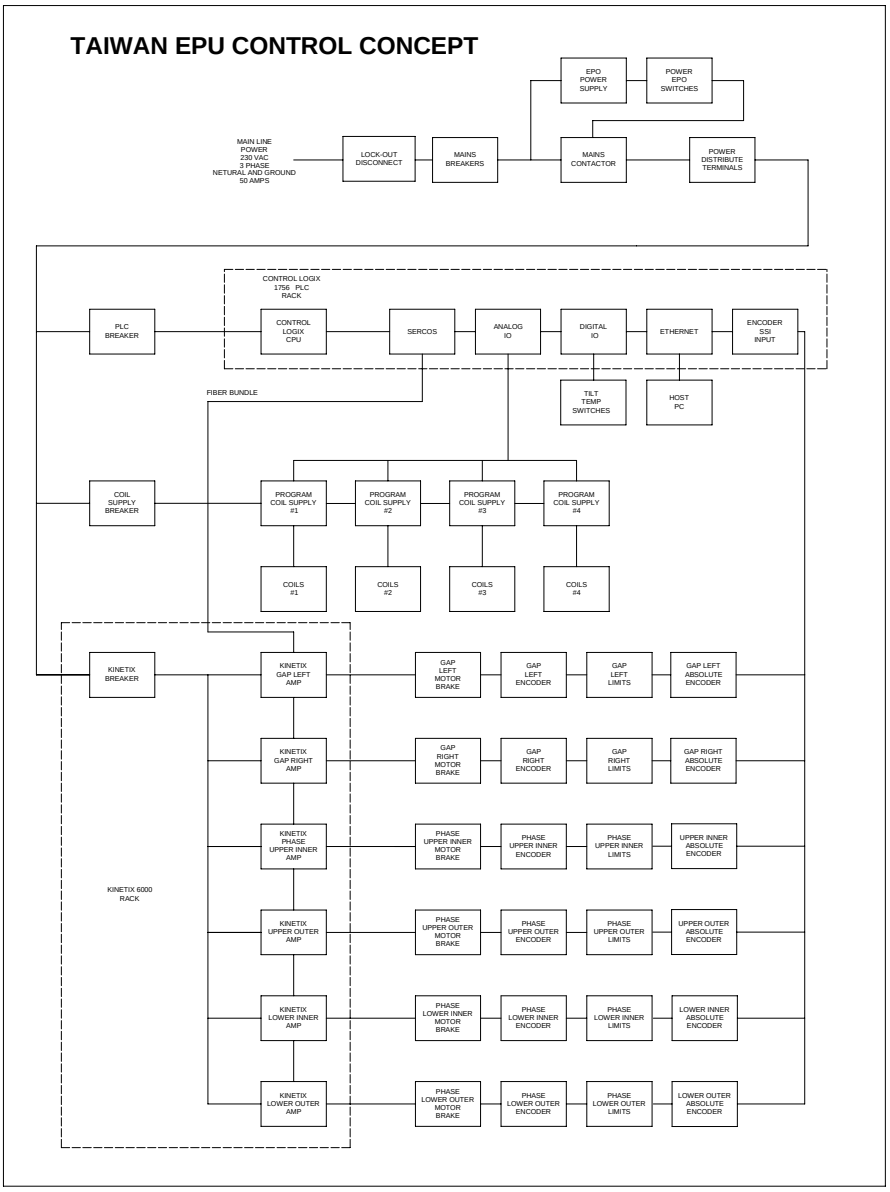
INTRODUCTION

The Insertion Device under control is a 4.6 meter Apple-II EPU. Challenging specs for gap repeatability and phase shift time (2 sec) drove the need for a high end, very sophisticated controller. This controller consists of an Allen Bradley ControlLogix PLC and an 8 axis Kinetix servo controller. Four servo motors control the gap, 2 on the upper girder and 2 on the lower girder, and another 4 servos controlled the phase, 2 on the upper girder inner and outer and 2 on the lower girder, inner and outer. Each axis servo motor employs a rotary absolute encoder capable of up to 790,000 counts per rev and a total of 4096 revs. In additional, each servo axis is tracked with a TR absolute linear encoder capable of .1 um counts. The linear encoder provides direct gap dimension sensing, referenced to the frame, that virtually eliminates the effects of backlash. The PLC performs a software tilt calculation based on feedback from the linear encoders which is significantly more accurate that typical tilt switches and faster acting (4ms). 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. A control architecture is shown below.

DESCRIPTION

The PLC manages all aspects of the control; gap positioning, correction coils, phase motions, error detection and recovery, and host interface. No other CPU, VME, or PC is needed. The AB ControlLogix-Kinetix servo system has the capability to slave multiple axes to a master or virtual master. Slaving to a virtual master has the benefit of reducing the net following error between real axes because those axes following a virtual master should all have the same following error. Due to potential radiation damage to the electronics and remote access for maintenance while the beam line is running, the PLC and Kinetix servo amplifiers are mounted outside the ring at an anticipated distance of 60 meters (the servo motor cable limit is 90 meters). Two 19 inch cabinets are anticipated due to the size of the PLC and Kinetix racks but also due to the size of the correction coil power supplied. Currently, 4 correction coil power supplies are planned but the need may grow to 6. A 12.5 inch color touch screen supports local operation

for test and trouble-shooting while providing a convenient feedback display of ID status and gap information. Communication between the touch screen panel and PLC is via Ethernet.



CONTROLOGIX PLC

The AB ControlLogix PLC comes standard with an RS232 interface but ADC will include an Ethernet Module. A 13 slot system is proposed for this ID unit. The Main CPU is the latest High Speed Logic 5500 CPU. The digital IO is based on 24 volts DC and is used for error checking and control. The Analog IO is required for 4 sets of correction coils. The SERCOS Module is a fiber optic interface to the Kinetix Servo controller. 8 channels of SSI encoder input support the absolute linear encoders.

Slot 1 - Main CPU
Slot 2 - Ethernet Module
Slot 3 - 32 Points Digital Input
Slot 4 - 32 Points Digital Output

Slot 5 - 8 Points Analog Input (for correction coils)
Slot 6 – 8 Points Analog Output (for correction coils)
Slot 7 – SERCOS Fiber Optic Connection to Kinetix servo rack
Slot 8 – 2 Channels SSI ABS Encoder Input
Slot 9 – 2 Channels SSI ABS Encoder Input
Slot 10 – 2 Channels SSI ABS Encoder Input
Slot 11 – 2 Channels SSI ABS Encoder Input
Slot 12 – Spare
Slot 13 – Spare

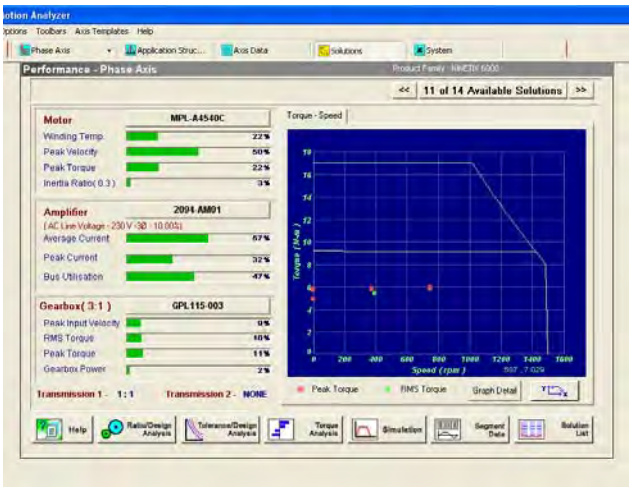
KINETICS SERVO CONTROLLER

The Kinetix Servo controller connects to the PLC via the SERCOS fiber optic loop. Eight motors are supported. The Kinetix system includes a power supply and line power conditioner that is dedicated to the servo motors. Amplifiers are mounted on a dedicated backplane rail. Each motor includes a brake and an absolute rotary encoder. The rotary encoder closes a velocity servo loop for stability and the linear encoder closes the position loop. The brake holds the motor in place with power off. All servo motors are identical to reduce spare parts inventory.

One of the primary advantages of the 4 motor concept for gap control is superior position repeatability over the single motor design. The reason is that ball screws are difficult to grind to the accuracy tolerance required to meet +/-5 um repeatability spec required for a single gap motor concept. However, our experience with Max-Lab has shown +/-1 um is possible over 2.8 meter girders independent of ball screw tolerance. Also, single motor gap control designs also have no way to correct for tilt error or to provide some degree of taper which is preferred for EPUs (to control first integral errors).

The 4 gap motors must move the girders symmetrically about the beam line to avoid skewing the beam. This is best done with servo motors to reduce the error in transit. Stepper motors only correct position errors after the move is complete, thus leading to the possibility of developing tilt error while in transit from one gap to another. The AB Controllogix PLC controller is quite capable of contour positioning these servos using two encoder feedbacks (rotary and linear) that correct for tilt errors while in motion.

PERFORMANCE



ADC performed a servo motor sizing to ensure we could meet the 2 second phase shift spec. Allen Bradley provides a sophisticated program for motor sizing called Motion Book (a free download from www.ab.com). The following result is based on a 5 pitch lead screw, 10:1 gearbox, MPL B420 servo motor, 1000 pounds load, 4000 pound thrust (to overcome magnetic attraction) and a 2 second motion profile for ½ period. From the plot it can be seen that this application hardly stresses any components.

LIMIT AND KILL SWITCHES

All axes will have limits and kill switches on either end of travel that actuate just before contacting the hard stops. Limits will only stop movement in that direction, allowing the PLC to back off the limit in the other direction. Kill switches will shut down the amplifiers and/or disable the PLC. It is not necessary to hand crank the

axis off a kill switch; ADC provides a custom optical interface card where the kill switch can be defeated, in order to back off a kill switch without going inside the ring. This card also provides a convenient maintenance break-point by indicating switch status directly from the switch outside the ring.

ENCODERS

The absolute encoder signal is fed back to the amplifier using SSI. SSI is a Synchronous Serial Interface similar to I2C where clock and data lines are employed. The PLC has special modules to receive this interface. The rotary encoder also uses the same SSI interface but is received at the Kinetics amplifier. Since these encoders are absolute, they do not lose position through a power cycle as incremental encoders do, thereby eliminating the need to Home any axis. The dual encoder approach also provides some degree of safety as the gap can still be positioned in the event that one of the encoders is lost. Both encoders use differentially driven digital signals that are extremely noise insensitive and can travel thousands of feet without degradation.

CORRECTION COILS

The correction coils will be controlled with 4 separate, programmable, bipolar, linear, DC power supplies from Kepco. Each supply will accept a 0-10 v analog signal for current and return with a scaled 0-10v signal for actual current. A key specification to update the correction coils at 200 Hz is required but is considered possible under a fast task in the PLC. ADC will provide the software that will interpolate the correction coil data stored in 1 dimensional arrays based on actual gap. It may be necessary to expand the data arrays to 2 dimensional arrays if the phase must be considered as well as gap.

SOFTWARE

ADC will provide all software for the Controllogix PLC that will set-up, configure, and prepare the system for service. In addition, ADC will provide software to control the gap for motions that expand equally about the center and also to hold a specific gap that can be shifted about the center. Some degree of taper is also allowed which is usually helpful to EPU Apple-II ID units. Host interface software will consist of response to commands and the update of status and error conditions, via Ethernet. ADC will also provide software for the touch screen including licenses and panel development software.

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