IN-VACUUM UNDULATOR CONTROLLER DESIGN FOR SSRF

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Abstract

Two 25mm period in-vacuum undulators (IVU25) have been installed in SSRF 3.5 GeV storage ring. The controller for IVU25 based on Siemens S7-300 PLC is used to control two stepper motors for the gap and tapper of magnetic pole array. The controller monitors cooling water's temperature and flux, monitor the array's temperature, too. And configure Ethernet access for remote control as well as MPS and PPS interlock. A simple user interface supports routine operation and detail information is showed at cascading windows. With real time feedback of the linear absolute encoders (LAEs) the tracking precision of gap and taper are less than 1 micron. This paper describes the design of controller hardware and software.

INTRODUCTION

Shanghai Synchrotron Radiation Facility (SSRF), currently in routine operation stage for nearly one year, is a 3rd generation light source in China. The first installed SSRF insertion devices, including two in-vacuum undulators (IVU25), two multi-pole wigglers and one elliptically polarized undulator[1], were designed by the SSRF team and manufactured in China.

The development of the in-vacuum undulator was started at the March 2008 and commissioning in January 2009. The girder of magnet arrays are driven by two stepper motors with gear reducers and screw systems. One motor control entrance gap and other control exit gap. The taper of the arrays depend on the difference of two gaps. Both motors can be controlled to run in synchronized way or uncorrelated way. Four LAEs measure the entrance gap and exit gap of magnet arrays. With sophisticated correction in due course the controller can keep the magnet arrays in parallel or with given taper during gap changing and get the defined position exactly.

ARCHITECTURE

The architecture of undulator controller is showed in the Figure 1. The controller is based on Siemens S7-300 PLC. The position information is derived from four LAEs with synchronous serial interface (SSI). PLC's SM338 module can get data from LAE within 0.5ms. During motors keep moving, PLC judges continuously whether motors have reached destination and judges whether the taper are out of the permission.

For safety of motion the controller has be designed the hardware interlock frame which consists of the stepper motors brake, position limit switch and kill switch, and a logical circuit. Besides local operator panel, HMI via MPI, the controller also provides remote interface via Ethernet for EPICS.

In the IVU25 controller, a special design to enhance motion synchronicity is the pulse channel selector (PCS). The PCS is used to deliver two synchronized pulse strings to stepper motor drivers so that the motors run in synchronization. In the mean time, the pulse channel can be switched out individually to modify pulse number for correcting taper.

Communication for remote control is accomplished using an EPICS driver between the SSRF control system host and the PLC by TCP/IP of Ethernet. The PLC send and receive certain dedicated variables of position, velocity, status and so on.

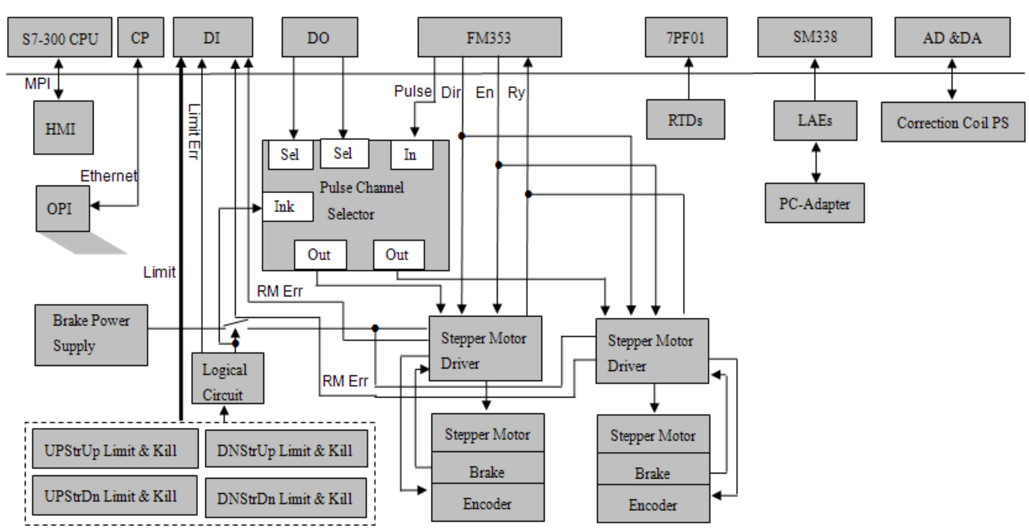

Figure 1 : The architecture of controller

SOFTWARE DESIGN

The control program is composed of two parts, one is based on PLC to operate IVU, and the other is based on EPICS for remote control. PLC's task modules consist of motion control, LAEs reading, temperature and flux monitor, safety protection, communication and etc. The major routine module is motion control in which a real-time modulating technique is made for high precision location. The local operation panel (HMI) is programmed with WinCC Flexible and linked to PLC via MPI (Figure 2) .

The remote operation interface based on EPICS is same as HMI. PLC sends the real time information of position, velocity, protection status and so on. The remote operation commands are received by PLC and the monitor routine evaluates the commands and then executed. It is important for machine safety that there is disallowed for operator to set PLC control bits directly.

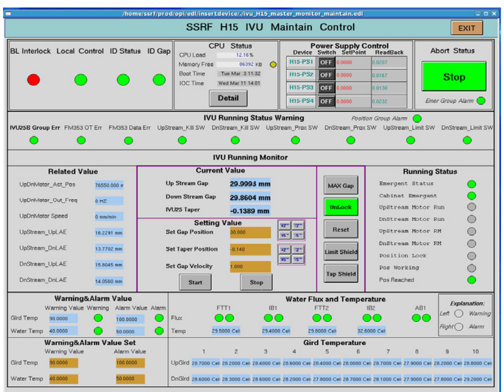

Figure 2. Operation Interface

IMPLEMENTATION

The routine operation of PLC program are position control, cryogenic monitor, interlock protection remote communication. The figure 3 shows the layout of LAEs and protection switches.

Position control

Four LAEs measure the both end position of magnet arrays respectively. The PLC program calculates entrance gap, exit gap and taper of the arrays, then issue the correcting action. Benefiting from the sophisticated performance of LAE and S7 PLC, The monitor program is made to so short scan time that it has better positioning accuracy. The program is designed to make position correction in time. The scan time of monitor routine is kept within 20ms. For 1mm/s of gap changing rate it is ensured that the deviation of gap (taper) will be restrained within 20 micron while the arrays running. When the girder is driven to approach the defined position the driving rate will be decreased according to motor's speed curve for the program has enough time to correct the deviation of position.

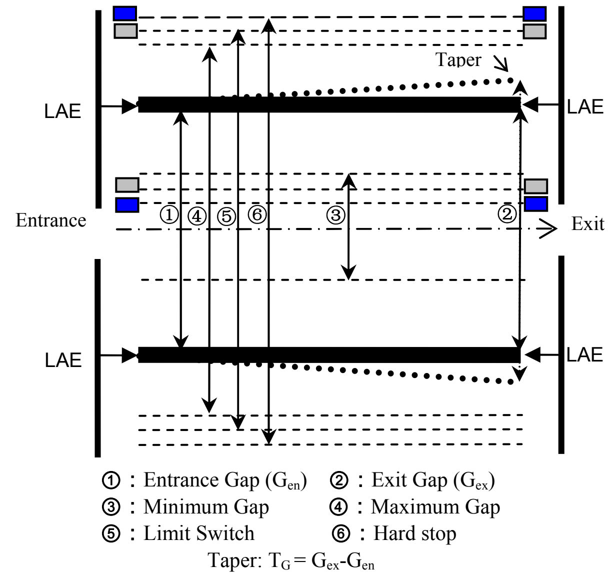

Figure 3: Schematic diagram of LAEs and limit switches

Machine protection

While the magnet arrays motion, the controller must ensure they do not overstep the limit of designed region as illustrated in the Figure 3. There are three ways to prevent the gap overstep the limit, mechanical block, limit switch and software limitation. Mechanical blocks placed close to the ball spindles are used to block off the arrays if the limit switch or software limitation failed. The limit switches will cut off the step pulse to the driver when it is reached and a signal will be sent to PLC. Software limitation is based on measurement of LAEs. The monitor routine will stop the step pulse to driver when the arrays reached maximum gap or minimum gap. The monitor program will obtain and show the information to operator and for flexible the operation of return from limited position is permitted.

Flow-meters and RTDs are detected by monitor program. There are two threshold for flux and temperature, warning value and protecting value. The monitor will alarm if the value reached warning value and take protecting action when it reached protecting threshold.

Interlock

The IVU interlock is linked to MPS and PPS system of the facility. Either MPS or PPS will excite the controller to drive the magnet arrays to maximum gap interval and set up the signal of maximum gap status when the gap located at maximum position.

CONCLUSIONS

The control system has been equipped to support routine operation and provide interlock protection to the SSRF IVU25 since April, 2009. Some improvements have been made for robust function and reliability. The performance of IVU25 controller is as follows:

- gap range: 7 ~ 18mm
- taper range: ±0.5mm
- gap velocity: 0.01-1mm/s
- step size: <1μm
- measure resolution :0.1μm
- position precision: ±1 μm

Some works are underway. One task is control of correction coil power supply (CCPS). CCPS and its control module has be made and tested. The control module will be integrated into main program of PLC to improve the correction function which was implemented originally by soft IOC in EPICS through RS232 interface. The PLC correct routine will be fast enough to follow gap changing. Another improvement has been made is the gap scan function with rate of 1 micron per second.

REFERENCES

[1] M.H.JIANG,et.al., "Shanghai Synchrotron Radiation Facility" ", Chinese Science Bulletin, November 2009, vol. 54 no. 22.

[2] Joe Kulesza, et al., "Design of control instrumentation of two in-vacuum undulators IVU25", Proceedings of PAC07, Albuquerque, New Mexico, USA.