Control System for an APPLE Type Undulator

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Abstract

Control system for the APPLE type undulator was constructed in accordance with the directions of SPring-8 standard for software development. This paper presents the configuration of the control system and describes the mechanism of software. Examples of its operation and monitoring are also given.

1. Introduction

An APPLE type undulator was installed at the cell number 23 in the SPring-8 storage ring in February, 1998. Since then, we have adapted the control system for the undulator following the directions of SPring-8 standard for software development. According to this standard, the control program must be written to satisfy a standard format known as Equipment Manager (EM).

Beam users can operate and monitor the undulator from a workstation GUI panel located at the experiment hall. They need send control commands under a rule of sequence: "subject", "verb", "object", and "complement", named SVOC commands. For example, when user wants to change the gap distance from some value to a target value of, say, 36.0 mm, he simply needs to key-in "subject/put/bl_id23_gap/36.0mm" at the workstation GUI panel.

The control system is composed of a computer, computer I/O (equipment interface boards), programmable controller (PLC), sensors, motors and a software. The software translates user requirements to an action of the undulator and, in turn, displays the eventual changes of undulator state on the GUI panel.

Here, the undulator action means a change in gap distance or a change in phase position of two magnet arrays. The phase can be put on in a periodic pattern movement. In order to suppress the closed orbit distortion (COD) of stored electron beam induced by the gap and phase movements, we excite a pair of steering magnets (for Bx and By magnetic fields). The excitation current intensity and excitation period are conducted by the software.

The objective of this paper is to present briefly the configuration of control system and the status of software development.

2. Configuration of Control System

The control computer is of a VME-bus-based type with 100 MHz of clock rate, 64 Mbytes of RAM and 20 Mbytes of flash ROM. The Operating System is real time HP-RT, and it is stored in the flash ROM. This computer receives via Ethernet SVOC commands from the beam users workstation or from a workstation of central control room. The VME modules and other control components are connected as shown in Fig. 1.

2.1 Computer I/O

Computer I/O or VME modules are interface boards needed to collect signals from sensors (limit switch, rotary-encoder and linear scale) and send computer-processed signals to command motor-drive amplifiers and power-supplies of magnets. The following six types of VME modules are used:

a) PTG board: to generate pulse trains to drive a pulse-motor (for array gap) and servo-motors (for array phase)

b) DI board: to receive signals from rotary-encoders (for array gap and phase), limit switches (for array gap and phase), vacuum gauge controllers, and ion pump controller (5 V, 24 V)

c) TTLDI board: to receive signals from linear scales for array gap and phase (5 V)

d) DO board: to send preset signals for rotary-encoder and linear scale controllers (24 V)

e) TTLDIO board: to send latch signals for rotary-encoder and linear scale controllers (5 V)

f) RIO board: for communication between RIO (remote I/O) master card and slave card.

2.2 PLC and Sensors

Two PLCs were introduced here to "pre-process" signals coming from sensors before sending them to the computer. The PLCs play an important role of reducing the number of connecting cables and adjust voltage level (from 12 V to 24 V, or from 24 V to 5 V). For example, note in Fig. 1 that the PLC no. 1 receives signals from the limit switches, emergency buttons, all steering magnets and ion-pump, processes these signals and then sends them to DI board through a reduced number of cables. This PLC is also responsible to display interlock status locally on the control panel, indicating eventual malfunctions of the entire undulator system.

Similarly, the PLC no. 2 receives Gray code

signals from the rotary-encoders for the array gap and phase, and converts to values of gap distance and phase position expressed in terms of BCD code.
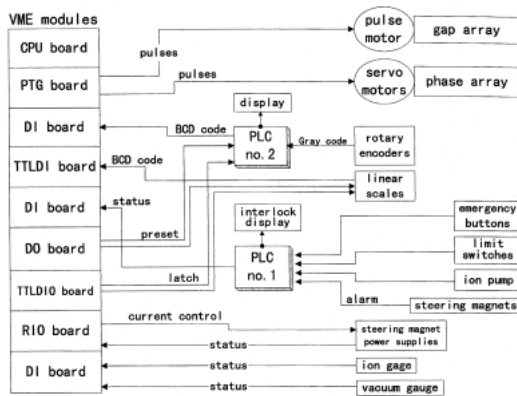

Fig. 1. Schematic of Control System for Undulator ID23.

After that, it sends BCD code to the displays and DI board. In addition to rotary-encoders, linear scales also measure the same gap distance and phase position. While rotary-encoders are located away from the permanent magnet arrays (located at the motor side), linear scales are attached on the lateral side of magnet arrays. We adopted this two methods of measurement to guarantee a high degree of accuracy (of 1 micron) and high reliability. The allowed differences between values from the rotary-encoders and linear scales are less than 20 micron for gap distance and 100 micron for phase position, otherwise an alarm sounds in the central control room.

2.3 Motors for Gap and Phase Drive

The array gap is driven by a pulse motor capable of rotating by 0.72 degrees per pulse. The gap distance takes a value ranging from 36 mm to 300 mm. Thus, it takes approximately 7 min to drive the gap from the maximum to the minimum position of 36 mm. The rotation speed of the motor can be changed by modifying pulse parameters written in a list of devices named configuration table.

On the other hand, the upper-side and lower-side magnet arrays are driven by servo-motors capable of rotating by 0.18 degrees per pulse. The phase-shift (relative longitudinal distance between two magnet arrays) can be altered from -120 mm to 120 mm. Also here, the pulse parameters for phase movement are written in the configuration table. Both this configuration table and the software are downloaded from a specific file server to the computer.

2.4 Power Supply for Steering Magnets

The undulator is equipped with a pair of long-steering magnets and four pair of AC-steering magnets. The power-supplies for all these steering mag-

nets are of bipolar type with a nominal output current of 15 A (-15 A) at 10 V (-10 V). They were designed to operate at 100 Hz of current intensity variation. Power-supplies receive control commands from the computer via optical fiber I/O (RIO). The interface board located at computer side is named master card and those located at power-supplies side are slave cards.

3. Description of the Software

There are three computer stored program files necessary to put the control system into operation: software EM (file name: "rpc_em_rt"), configuration table (file name: "config.tbl") and correction table (file name: "bl_id23_steer0.tbl"). The EM is in charge to organize and coordinate all VME modules (PTG, DI, DO, RIO boards). The configuration table is a text file of SVOC commands accompanied by the name of VME modules (device names) and device parameters to be called. The correction table is also a text file which gives matrices of current intensity of steering magnets as a function of gap distance and phase-shift.

When beam user sends a SVOC command from the GUI panel, for example "subject/put/bl_id23_phase/32.0mm", the EM interprets it based on the configuration table, and calls the PTG board to transmit the phase distance to be moved is 32.0 mm. Well, looking for a line in the configuration table where is written the command "put/bl_id23_phase/32.0mm", we observe the device to be called is "dev_ptg0350_2", and the pulse parameters are "30000", "1", "30". The first parameter "30000" indicates the maximum rate of pulses to be generated in pulse/sec, the second is the minimum rate (pulse/sec), and the third is an interval of time necessary to change the rate of pulses generation. The array gap and phase can not be driven simultaneously.

The EM was developed at a specific file server and then downloaded to the computer. When the storage ring is on beam users time, no new-download is permitted even if the change in source code is very small.

4. Movement of Gap and Phase by Exciting Long-steering Magnets

A good example to comprehend the mechanism of EM is to analyze the movement of gap or phase where the long-steering magnets are excited automatically. We use the method of feed-forward control to excite magnets. Now, let us follow some steps of software where one loop of feed-forward control is executed.

a) open the file of correction table

(bl_id23_steer0.tbl).

b) read present value of gap distance or phase-shift (read by linear scale)

c) subtract from this present value of gap distance or phase-shift a desired target position.

d) calculate the total number of pulses to drive the motor.

e) send a pulse train to the motor (motor starts here)

f) read transient value of gap distance and phase-shift consecutively during the movement. (read by linear scale)

g) determine excitation currents from the correction table by interpolation using values of gap distance and phase-shift.

h) set all values of excitation currents to a data register of RIO master card.

i) transfer the values of current from RIO master card to slave card to give currents to long-steering magnets.

j) read new values of gap distance and phase-shift at a next position and determine new excitation currents.

Steps (f) to (i) repeat in a loop with a period of 0.2 sec during all the movement until the gap or phase reaches its target value. The motor stops when PTG board finishes the generation of pulses.

The excitation of steering magnets by the method of feed-forward control as shown here was prepared using the programming technique of recursive call, in which a SVOC command can be emitted inside the other SVOC command. Some recursive calls can be observed on the above steps, such as the SVOC of "put the current (steps (f) to (i))" emitted inside another SVOC of "move the gap distance or phase-shift until a target value (steps (b) to (e))".

5. Monitoring of the Undulator

Beam users can monitor the machine status of undulator by emitting a SVOC command like "get/bl_id23_ivg_1/pressure" to know if the chamber vacuum pressure is at a satisfactory level. On the other hand, if eventually any malfunction occurs at the servo-motors, he can emit a command like "get/bl_id23_phase/status" to know the state of alarm of servo-motors. There are 24 "get" commands to be monitored. The replies of "get" commands represent undulator status and are transmitted to the database server every 10 sec.

6. Summary

During the year of 1998, we realized the software for the undulator ID23 in the format EM and studied its software performance. During the coming year of 1999, we are planning to improve the software focusing on the following themes:

(a) create an independent computer process specialized for periodic movement of phase.

(b) excite simultaneously all steering magnets (long-steering and AC-steering magnets)

References

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[2] Y. Teraoka, SPring-8 Annual Report 1997, 118 (1997).