

Development of EM Software for the Dynamic Excitation of Steering Magnets in an APPLE Type Undulator

Yoichi HIRAMATSU, Taihei SHIMADA, and Yoshikazu MIYAHARA
 Japan Synchrotron Radiation Research Institute (JASRI)
 1-1-1 Kohto, Mikazuki-cho, Sayo-gun, Hyogo 679-5198, Japan

Abstract

Control software for an APPLE type undulator was developed. The major capability of this software is to make a fast correction of the closed orbit distortion (COD) of an electron beam by exciting steering magnets at a rate of time interval of 24 msec (42 Hz) during the movement of permanent magnet arrays of the undulator. This paper presents the configuration of control system, the mechanism of the software and its performance. Some results of preliminary experiments are also discussed.

1 Introduction

An APPLE (Advanced Planar Polarized Light Emitter) type undulator was installed at the cell number 23 in the SPring-8 storage ring in February, 1998. We have developed the software of the control system for this undulator in accordance with the directions of SPring-8 standard for software development. According to this standard, the software application programs must be written to satisfy a standard software frame format known as EM-frame (Equipment Manager). The objective of this standard is to let beam users develop and maintain their own application programs by themselves with the minimum assistance of SPring-8 technical staff. During beamline experiments, beam users need to change parameters of the undulator like gap-distance and phase-shift of the magnet arrays to change the energy or polarization of the undulator radiation, as shown in Fig.1. This EM-frame requires that the control commands take a rule of sequence: Subject, Verb, Object, and Complement, known as SVOC

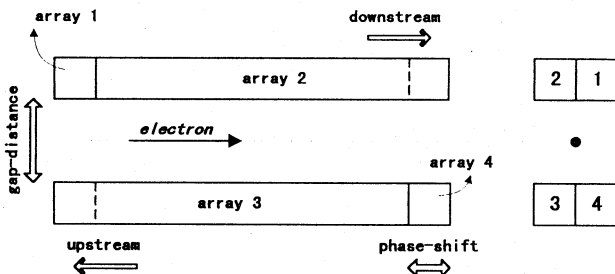


Fig. 1 Gap-distance and phase-shift of the magnet arrays

commands. Based on the EM-frame, a software process named EM was developed. SVOC commands can be emitted at GUI and also inside the proper EM by recursive-

calls. This property was adopted to excite 10 steering magnets during the movement of gap and phase position of permanent magnet arrays. We confirmed by experiments a rate of time interval of 24 msec for excitation cycles. At the present stage of storage ring, this rate is sufficiently fast for the COD correction. The objective of this paper is to present briefly the configuration of control system, the structure of software EM and its performance by discussing some preliminary experimental results.

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 which is placed near the undulator together with several power-supplies for the undulator. The OS is real-time HP-RT (version 2.21, already corrected for the computer problem of the year 2000), and it is booted up by the flash-ROM. The process EM runs on this computer. VME modules and control components are connected as shown in Fig.2.

2.1 Computer I/O

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-supply of magnets. The following six types of VME boards are used: PTG, DI, DO, TTLDI, TTLDIO, RIO boards.

2.2 Sensors

As shown in Fig.2, two Programmable Logic Controllers (PLC) were introduced to pre-process signals coming from sensors before sending them to the computer. The PLC plays a role to reduce the number of connecting cables and

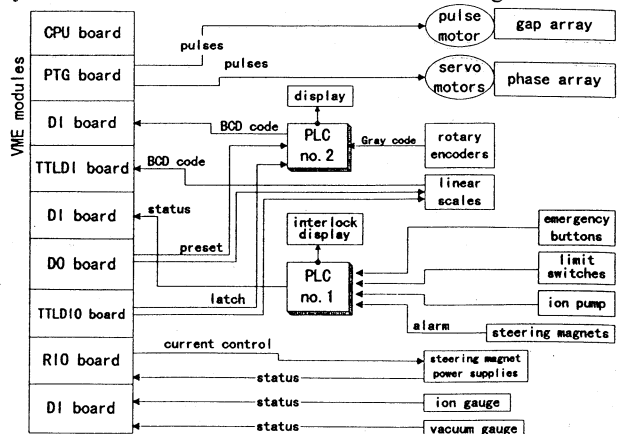


Fig.2 Schematic of control system for undulator ID23

adjust signal voltage level. Also, the PLC receives Gray code signals from the rotary-encoder for the arrays gap and phase, and converts to values of gap-distance and phase position. Rotary-encoder and linear-scale measure the same gap-distance and phase position. While rotary-encoder is located away the magnet arrays (located at the motor side), linear-scale is attached on the wall of magnet arrays. We adopted this two independent methods of measurement to guarantee a high degree of accuracy and high reliability of control.

2.3 Motors for Gap and Phase Drive

The array gap is driven by a pulse-motor capable of rotating by 0.72 degree per pulse. The gap-distance takes a value ranging from 36 mm (minimum) to 300 mm (full open). The rotation speed and acceleration of the pulse motor can be changed by modifying drive parameters written in a list of devices named configuration table. The upper-side and lower-side magnet arrays are driven independently by two servo-motors capable of rotating by 0.18 degree per pulse. The phase position can be altered from 60 mm to -60 mm. For the convenience of beam users, we introduce here a definition of phase-shift as a relative longitudinal distance between upper-side and lower-side magnet arrays, or that upper-phase minus lower-phase positions. So, the phase-shift takes a range of values from 120 mm to -120 mm.

2.4 Power Supply for Steering Magnets

The undulator is equipped with 10 steering magnets. The power-supplies for all steering magnets are of bipolar type with a maximum output current of 15 A (-15A).

3 Description of EM Software

EM is the name of executable code (a software process) resulted from the EM-frame. As shown in Fig. 3, EM is a server-process that organizes and coordinates all VME

modules when it receives SVOC commands from the client-process GUI.

3.1 Steps to Develop EM

The first task of a programmer is to define what type of primitive and independent movements can be achieved from the particular hardware system. This definition is necessary to produce a series of combined movements, such as of gap and phase movement. Each primitive movement needs be expressed in the style of SVOC command. The second step is a preparation of the configuration table, which is a list of all SVOC commands and the name of application programs accompanied by the name of devices and their parameters. The third step is the preparation of application programs. They are in a number of hundreds depending on the complexity of the system. The purpose of this policy is to help users to understand easily the mechanism of EM, saving therefore the coding time during debugs and posterior software improvements. The last step is a preparation of Makefile to compile the programs.

3.2 Characteristics of EM and SVOC Commands

The merits to adopt the standard EM and SVOC commands come from the following characteristics: (a) new application programs could be added easily to the existing EM when other movements are required, (b) EM can be rebuild easily when newly-released CPU is introduced, and (c) specific tasks could be accomplished by creating child-processes.

3.3 Performance of EM

EM is booted up when one power-on the VME computer. During the boot up, EM calls two files: (a) configuration table and (b) current excitation table. As mentioned, the configuration table is a list of commands followed by the name of programs, the name of VME devices, and parameters. The excitation table gives matrices of current intensity as a function of gap-distance and phase-shift, necessary for the excitation of steering magnets during the change of gap or phase.

When the beam user emits at GUI a SVOC command like "put/bl_id23_gap/300.0mm", EM interprets this through the content of configuration table, that is associating the verb "put" and object "bl_id23_gap" with the VME device and device parameters. Here, the VME device is PTG board and parameters are pulse generation rates of the motor. After the interpretation, EM transmits to PTG board that the number of pulses necessary to move from present gap 36.0 mm to target gap 300.0 mm is 1,320,000 pulses. Similar to the case of gap, for the command "put/bl_id23_phase/32.0mm", EM calls API to transmit to another PTG that the number of pulses is 3200 pulses (moves downstream) for upper-side array and 3200 pulses (moves upstream) for lower-side array, because phase-shift of 32.0 mm means that the target for the upper-phase array is 16.0 mm and for lower-phase is -16.0 mm.

When EM receives the command

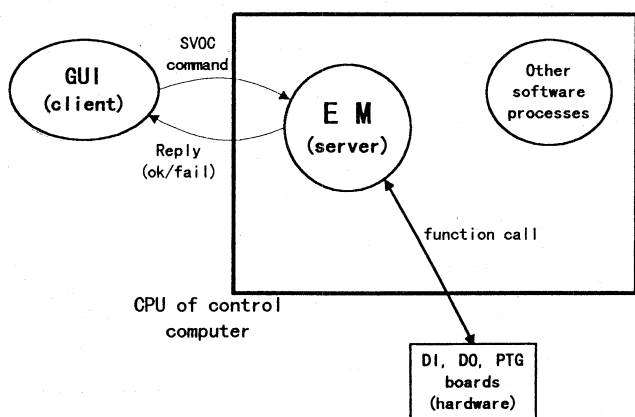


Fig. 3 Process EM on the control computer

"get/bl_id23_gap/position" it returns actual gap-distance to the client GUI. Since EM is by nature an application of C-language compiler, it accepts recursive-call of SVOC commands inside the proper EM. So, the reply like 123.0 mm (read by linear-scale at a short time-instant) corresponding to the above command can directly be returned to the own EM, instead of to GUI. This software property was utilized to excite all steering magnets during gap and phase movements by calculating dynamically the intensity of excitation currents.

4 Results of Excitation of Steering Magnets

4.1 Gap Movement

In the first test, the gap-distance was altered from 36.0 mm to 300.0 mm (opening gap) at the phase-shift fixed to 0.0 mm. Fig. 4 is a result of the gap movement, where the vertical coordinate indicates gap-distance and the horizontal one elapsed-time. We see in the figure that the velocity of movement keeps constant and the steering magnets are excited at a rate of time interval of 24 msec. Each excitation (like of "st_h_1") occurs 16 msec after the reading of gap by the linear-scale. The period of 24 msec is determined by hardware factors, such as reading response of the linear-scale, processing speed of CPU, response of I/O devices, etc. During the recursive-calls no other command is accepted, so that the gap or phase movement and steering magnet excitation are not interrupted until the movement is finished.

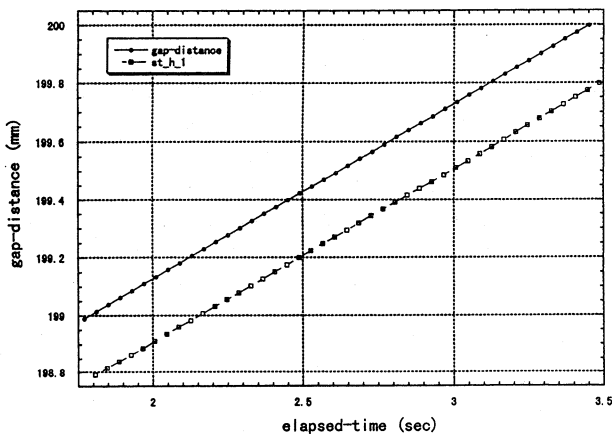


Fig. 4 Movement of gap (the frequency of excitation of steering magnets is 42 Hz)

4.2 Phase Movement

In the second test, the phase-shift was changed from -100.0 mm to 100.0 mm at the gap-distance fixed to 300.0 mm. Fig. 5 is a result of the phase movement. The vertical coordinate indicates phase-shift and the horizontal one elapsed-time. We see here that the magnet arrays are accelerated at the start of movement until they reach a constant velocity. Then, before stopping they are decelerated smoothly. The acceleration curve is defined by parameters of pulse generation rates written in the

configuration table. There are no mechanical overshoots because optimum parameters were obtained by previous experiments[2]. Equally to the case of gap, the period of excitation for all steering magnets is 24 msec. In the figure, each excitation (like of "st_h_1") occurs 16 msec after the reading of phase-shift by the linear-scale.

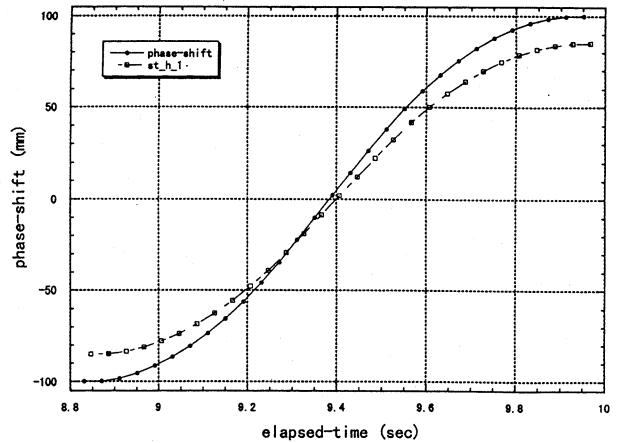


Fig. 5 Movement of phase (the frequency of excitation of steering magnets is 42Hz)

5 Conclusion

The main characteristic of the APPLE type undulator which differs from other type of undulators is the phase change by moving magnet arrays during beamline experiments. We developed the software EM to control the undulator using the software resources of SPring-8. EM has a property of recursive-calls and this was applied to excite dynamically the steering magnets. The satisfactory result of period of 24 msec was obtained for excitation cycles. In coming machine studies, we are planning to improve the software performance based on new experiment data of COD correction.

Acknowledgement

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References

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