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HESYRL Control System Status

Yao Chih-Yuan
Hefei National Synchrotron Radiation Laboratory
U.S.T.C.

Abstract

HESYRL synchrotron radiation storage ring was completed in 1989 and has been in commissioning since then. Now it has met its design specification and is ready for synchrotron light experiments. Control system of the project was completed in 1989 and some modifications were made during commissioning. This paper describes its present configuration, status and upgrading plan.

I. INTRODUCTION

Hefei National Synchrotron Laboratory (HESYRL) is a dedicated synchrotron light source. It's main facilities are a 200 MeV electron linear accelerator, a beam transport line, an 800 MeV electron storage ring and the experiment stations.

Design and construction of the ring and linac control system started in Oct. 1984. The linac control system was completed in 1987 and the ring control system was completed in 1989. Modifications have been made to the system during two years of machine commissioning, including RF control, vacuum monitoring and new control programs.

The ring control system is a distributed computer control system consists of a PDP11/45 computer, two PCs, a communication microcomputer system(CMM) and up to 40 local control microcomputer systems(LCM).

The linac control is essentially a manual control system.

A timing system consisting of two microcomputers provides all necessary triggering signals for the linac and the injection system.

II. RING CONTROL SYSTEM

A. System Configuration

Fig.1 is a block diagram of the ring control system.

Two PCs perform the main control function. Console display and command input are also performed on the PCs. The PDP11/45 minicomputer system, originally planned to be employed as the main control computer, is now only a part of communication system because of its limited memory and poor display ability. The two PCs are connected to the DZ11 ports of the PDP. Ring control programs are executed on the PCs.

Storage ring and beam transport line equipments are controlled and monitored by local control micros. The LCMs are located near the equipments. Each LCM controls only one or one type of equipments.

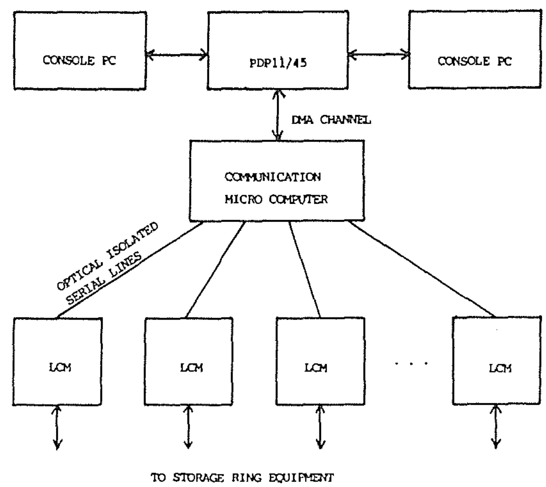

FIG. 1 BLOCK DIAGRAM OF HESYRL RING CONTROL SYSTEM

A LCM consists of a MULTIBUS crate, a SBC80/24 or SBC80/20-4 CPU board, a home designed serial interface and memory expansion board(HCOM) for communication and a few interface boards for equipment interfacing.

System communication is performed at two levels. The console PCs exchange data and commands with PDP through its serial lines. The PDP communicates with LCMs via a dedicated communication microcomputer system, which is a MULTIBUS system composed of a master SBC 80/24 CPU board, a DMA communication board and between 1 to 10 intelligent communication boards(COMM).

The COMM board is similar to Intel SBC544 intelligent asynchronous communication board. It has a Z80 CPU, 4 serial ports, on board RAM/ROM and dual port RAM memory which can be accessed by both a MULTIBUS master and the on board Z80. One COMM board can handle communication with 4 LCMs.

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The DMA board controls DMA data transfer between the dual port memory and a DR11-B DMA interface of the PDP.

The main control console is made up of 9 modified industrial cabinets which are equipped with terminals, video monitors and various control panels. It is functionally partitioned into several subpanels: transport line magnet control, injection system control, timing control, ring control, beam diagnosis, interlock and personal safety etc. Most of the operations are performed at the console PCs.

B. System Software

There are three levels of control programs.

ROM monitors of the LCMs are at the lowest level. The basic design idea of LCM monitor is brought from NSLS. It consists of two parts: a basic control monitor and an application part. The former initializes the micro, handles communication messages and schedules operation of different control processes. The latter is essentially a collection of interfacing routines designed for the particular hardware configuration. The Basic control monitor is identical for all the LCMs.

At the second level are communication programs including ROM control monitors for the communication microcomputer,and a DR11-B I/O driver for the PDP.

The main function of SBC80/24 monitor is to handle the data exchange between the dual port memory and the PDP. All data are transferred in DMA mode.

There is a ROM monitor program on each COMM board of the CMM, which manages communication with LCMs.

The I/O program for DR11-B interface is installed as a RSX11-M device driver which can be called by QIO.

Ring and transportline control programs are at the third level. Three programs are used for normal operation. A program called RINGTEST performs ring device status display, ring magnet current and RF voltage setting, console command interpretation, ring lattice adjustment, file saving and restoration, beam energy ramping process control etc. It mainly deals with hardware signals. The second is BLOS, which performs transport line and linac magnet setting and adjustment. The third program, CORRECT, does closed orbit correction.

Ring lattice modeling, ramping table generation, closed orbit analysis and other calculation are performed by off-line programs.

C. Equipment Interfacing

The LCMs are mainly partitioned into the following seven subsystems:

HESYRL ring has 1 dipole group, 8 quadrupole groups and two sextupole groups. The main magnet power supply control system consists of 12 LCMs, 11 of them are ramping magnet LCMs each controls one magnet power supply. A LSI-11 controlled CAMAC system and a DVM is used to read back DCCT values of all the magnet currents. The dipole LCM also contains a ramping timer board which is a synchronizer for all other LCMs. Fig. 2 shows the configuration of the main magnet control system.

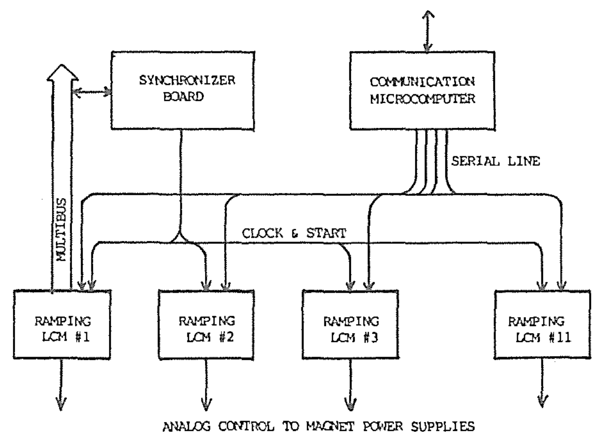

FIG.2 BLOCK DIAGRAM OF RAMPING CONTROL SYSTEM

The injection energy of HESYRL ring is 200 MeV, which is only 1/4 of its operation energy of 800 MeV. Ramping process is critical for high beam current.

During an energy ramping or ring configuration change process the currents of the magnet power supplies must follow certain calculated curve synchronously in order to keep the beam stable. In a centralized system the central computer has to modify magnet current one by one in many small steps. It will takes a lot of CPU time. The local intelligence of LCM allow us to take different approach. It is called table ramping. Ramping data are pre-stored to the LCMs. Synchronization of different LCMs is kept by hardware signals.

A ramping magnet LCM is composed of a CPU, a serial line interface, a ramping controller board and a 16 bit D/A converter board.

A ramping curve is divided into many small straight segments. Each segment is defined by its end current and slope values. As many as 1000 segments can be defined for one curve. A ramping segment is generated by counting up or down of a 16 bit counter on the ramping controller. The clock input to

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the counter is divided from a common clock output signal of the synchronizer. The ramping LCMs are programmed such that when a segment end is reached the new segment and slope values are loaded. The synchronizer also provides a start signal for all the ramping LCMs. Tracking of different magnets is automatically assured.

In order to start a ramping process, the main computer just needs to load the segment table, send necessary command to the LCMs and then issue a start command to the dipole LCM to start the synchronizer.

A fitting program is developed to calculate optimized ramping table for any required ramping process. The theoretical fitting error is 1 bit.

12 auxiliary windings of dipole magnets and 64 auxiliary windings of quadrupoles are configured as 12 horizontal and 32 vertical closed orbit correctors. Two LCMs are used to control all these corrector power supplies.

Control of transportline focusing and correction magnets are performed by system composed of a SBC80/24 LCM in the power supply room and a PC on the operator console. The PC acts as the control master and the LCM accepts PC command and performs the actual control.

The beam position monitor signals are needed on line for closed orbit correction. A PC data acquisition system is used to read and display the BPM data.

Ion pump currents and vacuum gauge pressure readings are monitored by a PC data acquisition system.

Injection system includes a pulsed septum magnet and three fast kickers. The triggering signals are provided by timing system. Pulse amplitude control are performed by a SBC80/20-4 LCM with a terminal on the operator console for command input.

HESYRL ring has only one RF cavity, so phase control is not necessary. A tuning loop is built for cavity tuning control. Detuning angle is controlled by a manual adjusted phase shifter. Cavity voltage is regulated by a feedback loop. A ramping LCM is used to control the cavity voltage. During ramping process the cavity voltage is controlled in the same way as the ring magnets and therefore can follow any desired curve.

III. LINAC CONTROL SYSTEM

The linac control system is divided into 8 separate subsystems each has its own control panels and controls one part of the linac equipment. The modulator control panels, klystron focusing control panels, electron gun control panels, microwave control panels, vacuum control panel are all manual control panels.

The 200 MeV linac has an extension section for future beam energy expansion. Linac focusing and correction magnets fall into two groups: 30 focusing and steering magnets for linac proper and 32 magnets for the extension section including a beam energy analyzer. They are controlled by two SBC80/20-4 LCMs and a PC. The PC serves as the master and operator console. The LCMs perform the local control and monitoring functions. The links between the PC and the two LCMs are fiber optical serial lines.

A SIEMENS S5-101 programmable controller is used for linac interlock and protection.

IV. TIMING SYSTEM

The timing system provides synchronization triggering signals for the linac, injection system and beam diagnose system. Since timing is only adjusted during injection and linac set up time and most of its parameters are fixed, It is built as an independent system. Two LCMs are implemented: a main timing micro(MTM) installed in the main control room and a linac timing micro(LTM) in the linac control room.

The MTM generates master start and clock signals which are the reference of the whole system. The master signals are transmitted to the linac timing micro. MTM also provides trigger signals for the septum, kickers and for beam diagnose system. The LTM generates trigger signals for the electron gun, the microwave source, the klystron modulators and the switching magnet pulse generator.

Structurally the two micros are almost identical. They consists of a CPU board and a timing generation board(TIG).

Present timing system can only be operated in full bunch injection mode.

V. PRESENT STATUS

During the commissioning period the control system has performed satisfactorily.

Timing system, linac and transport line magnet control subsystems greatly eased linac and transportline tuning. Resolution and delay adjust range of timing system are suitable for optimization of linac operation.

Injection control and ring timing systems assured conveniently setting of correct injection condition. The ring control program has a linear approximation trimming function to adjust the ring energy slightly up or down. This is very useful for matching ring and injection beam energy to improve injection rate.

The measured accuracy of ring magnet current setting is better than $7X10^{-5}$. This assured stable and repeatable ring lattice setting. The measured tune variation is less than .001.

The simple practical approach of RINGTEST control program served well in

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machine commissioning and normal operation.

Beam energy ramping control is very successful. With the table ramping technique energy ramping or transfer to different lattice is very easy and smooth. Current tracking was measured better than 10^{-4}. Beam loss rate from 200 MeV to 800 MeV with 200 mA current is less than 7%, which is of same order as normal lifetime loss. This is also a good indication of ramping accuracy.

System communication has been reliable, but the system response is slow. This is due to the speed of serial lines between console PCs and the PDP.

VI. PLANNED SYSTEM UPGRADE

The operation experience showed us that there exist several problems in the present HESYRL control system: 1) It is not a fully linked system. A few standalone subsystems are not connected. This is not convenient for system management and systematic data logging. 2) PDP is an old system and difficult to maintain. It becomes a weak point. 3) Lack of on-line calculation ability is not desirable.

Having analyzed these problems, and considering our available resources, we plan to make the following improvements:

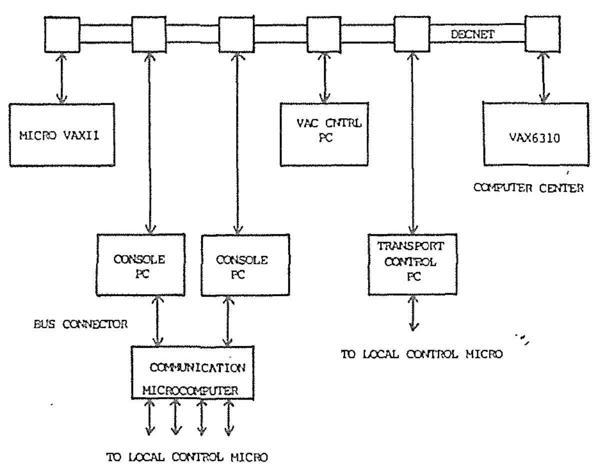

FIG.3 UPGRADE OF HESYRL CONTROL SYSTEM

1) Introducing DECNET to link the MicroVAXII, console PCs, transportline PC, vacuum monitoring PC and a recently installed VAX6310 system together. This will give us a fully linked system and much expanded computing power.

2) Replacing the PDP by two BIT3 bus connector cards which connect PC bus to MULTIBUS of communication system and directly map the dual port memory to PC memory. This will eliminate the bottleneck and increase data speed of the whole system

3) Improving console display and computation ability by replacing the console PC with more powerful 386 or 486 stations.

4) CATV is very convenient to display machine status information to the users and other laboratory staffs. Installation of a 10 channel CATV system is under way.

5) Control programs will be rewritten to include on-line calculation function and node to node communication.

VII. ACKNOWLEDGMENTS

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The control group have been working cooperatively over the years to build and maintain the system.

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