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Accelerator Control Systems in China

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Abstract

Three accelerator facilities were built in the past few years, the 2.8 GeV electron positron collider BEPC, the heavy ion SSC cyclotron accelerator HIRFL and the 800 MeV synchrotron radiation storage ring HESYRL. Aimed at different research areas, they represent a new generation of accelerator in China.

This report describes the design philosophy, the structure, performance as well as future improvements of the control systems of the these facilities.

I. INTRODUCTION

The development and research of accelerators in China has made good progress in the past thirty years. Many low energy accelerators for research and application have been constructed, including high voltage type accelerator, cyclotron, linear accelerator, betatron etc. Their application covers a wide range: medical treatment, industrial irradiation, non-destructive inspection, isotope production and many other fields. The three newly completed high and medium energy accelerator facilities, Beijing electron positron collider(BEPC), Lanzhou heavy ion research facility(HIRFL) and Hefei synchrotron radiation source(HESYRL), aimed at different scientific research areas, represent a new generation of accelerator facilities.

Early accelerators are mostly controlled by panel meter and push button type manual control system. Application of microcomputers to accelerator control system started at the beginning of 80's when microcomputers were becoming popular in China.

This paper is not intended to be a general survey. Control systems of the three new accelerator facilities, which are relatively larger in scale and more complicate in structure, are described here with the emphasis on the system architecture.

II. BEPC CONTROL SYSTEM

BEPC is the first high energy accelerator built in China. The main facilities of BEPC are a 1.4 GeV electron linear accelerator injector, a 1.4 GeV beam transport line and a 2.8 GeV electron storage ring. The project was started in 1984 and completed in 1989.

Because of the strict time table for the BEPC project, the leaders of the project decided early in 1985 that in order to reduce development work and shorten the construction period the new control system of SPEAR ring should be adopted as the base for BEPC.

BEPC control system is a typical centralized control system. A VAX11/750 serves as the central control computer. Serial CAMAC systems are the base for equipment interfacing.

1. System Configuration

Fig. 1 is a block diagram of BEPC control system. The system is functionally divided into three levels.

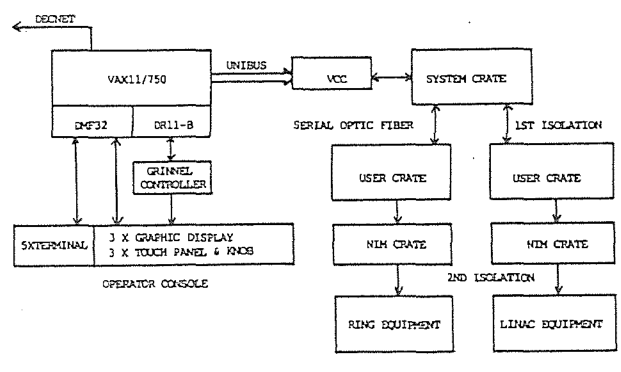

FIG.1 BLOCK DIAGRAM OF BEPC CONTROL SYSTEM

First, at the center of the system is the DEC VAX11/750 computer, which is equipped with a asynchronous serial interface board for connecting terminals and knobs, a DR11-B DMA interface for connecting color display monitors, and other standard peripherals such as hard disks, printers, tape drivers etc. A SLAC designed Vax CAMAC Channel(VCC) is the key element in data communication network. It is a DMA controller to interface VAX11/750 UNIBUS with CAMAC system. Two CAMAC system crates are controlled by the VCC, one for the linear accelerator the other for the storage ring. One system crate houses several serial branch driver modules and each branch driver starts a fiber optic serial high way loop which connects up to 7 user CAMAC crates. The second level is the local control stations formed by user crates. I/O functions are performed by the local control stations. Each local control substation controls one

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section of equipment, such as ring magnet system, vacuum system, transport line magnet system, RF system, linac magnet system, BPM system etc.

At the third level are NIM signal converter and isolator modules distributed at equipment site. The NIM modules must match BEPC hardware and are all developed by IHEP.

2. Software System

BEPC control software is a database driven system taking full advantage of multi-tasking ability of VAX/VMS operating system.

The database and its manager are the center of the system. All the machine hardware and program operation parameters are stored in the database which resides in a VAX global section shared by all software processes.

Software processes are executable programs under VMS operating system. They can be invoked by terminal command or by another process.

Two processes have special role in the system. A memory resident VCC I/O program CXCAMAC continuously performs I/O operation, sends out messages to CAMAC systems, collects status information from CAMAC systems and refreshes database records. The other special process is AVTX, which is a command receiver/interpreter and scheduler. It receives touchpanel and knob commands, decides which processes to call to perform the demanded operation, and activate appropriate processes.

Database generation and maintenance processes are also included in the system for ease of database initialization and modification.

Up to now, a total of 17 software processes are implemented for BEPC system, including ring magnet control and status display, ramping process control, BPM data taking and processing, closed orbit correction, ring lattice calculation, ring and transport line modeling etc.

3. Present Status

The system was completed in the middle of 1988, a few months ahead of first colliding beam experiment. After that it has been operated for beam colliding experiment and machine study for more than two years. System reliability is proved satisfactory. Some modifications has been made to the system to improve its performance. Dual speed Dual accuracy ramping function are developed for main magnets and correctors to increase the speed of ramping process. Analog control part of database is reorganized to enable more flexible and faster I/O operation. RF control function is added and a new BPM data acquisition program is developed to reduce BPM scan time and generate graphic display of beam position.

4. Upgrading Plan

Because of the centralized architecture, all control and monitoring operations must be initiated by VAX11/750. This takes substantial part of CPU time, especially during a ramping process. Many memory resident processes further increase the load of VAX11/750. The processing speed and response time of the entire system are not satisfactory. Further more, system reliability to some extent depends on the reliability of VAX 11/750, as it is the only controlling master. Another problem is that because of its limited processing power, VCC sometimes becomes the bottle-neck of message communication.

In order to overcome these problems, plan has been made to convert the centralized system to a distributed system. DECNET will be used to link the VAX11/750, A micro VAXII and a VAX Work-Station as three nodes. Fig.2 shows the upgraded system configuration.

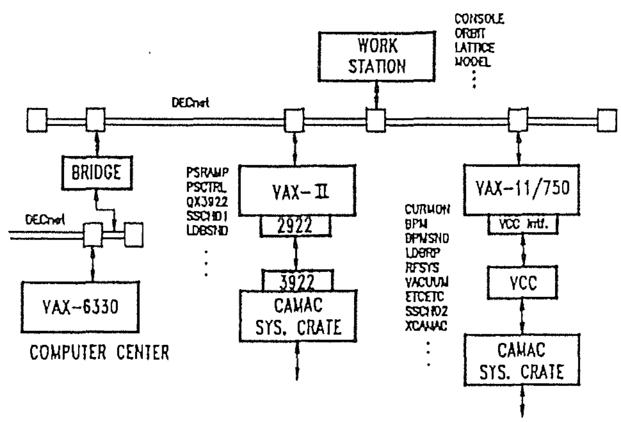

Figure 2 The upgrade of BEPC control system

The Micro VAXII will be dedicated to the task of magnet power supply control. The WS will be used to replace the present console terminals. The rich window software functions of WS will be fully utilized to update the man-machine interface. The WS will also share some of the calculation tasks, such as ring modeling, orbit calculation etc., with the VAX11/750.

A KSC 3922/2922 Q-BUS CAMAC adapter will be used to interface the Micro VAXII to the system crate for power supply control. The communication bottle-neck problem will be basically resolved, partly because the amount of messages through VCC are reduced substantially, partly because the QIO operation of 3922 is faster.

All hardware below the system crates will remain unchanged. This will ensure hardware compatibility.

The software compatibility among VAX family systems is an advantage for software upgrading. Except for the CAMAC I/O driver program, most of the software developed for VAX11/750 can be moved to Micro VAXII system and the WS with only minor modification.

In order to coordinate the processes on

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different nodes, new communication programs will be developed to enable inter-node and inter-process message exchange.

III. HIRFL CONTROL SYSTEM

HIRFL is a variable energy heavy ion accelerator. It consists of a 1.7 meter radius sector focusing cyclotron modified from a former 1.5 meter cyclotron as injector and a new built separate sector cyclotron. The project was started in 1976, and completed in 1988.

Control system of HIRFL is a distributed control system formed by a Vax cluster as the central computer and several microcomputer controlled CAMAC control substations(CSS).

1. System Configuration

Fig. 3 is a block diagram of the HIRFL control system. Two VAX8350 computers are linked together through the CI bus and DECNET to form a cluster. One of them, which serves as the central computer of SSC control system, interfaces to serial CAMAC system through a UNIBUS adapter and a serial branch driver. The other serves as a data processor, software development system and a backup system. The cluster is equipped with 2X12MB of memory, 4X520MB hard disks and other standard peripherals.

A DZ11 asynchronous interface, a DR-11 parallel interface and a parallel CAMAC branch driver are also installed on the UNIBUS for connecting console devices, including 6 touch panel monitors and 6 color monitors.

Serial CAMAC high way communication link is used for the whole control system.

A control substation is an intelligent CAMAC crate containing a serial crate controller which is the main controller of the crate an auxiliary controller for substation computer and other CAMAC modules. Control command may either be issued by the central computer or by the substation microcomputers. Communication between the central computer and substation computers is also performed via the serial high way. A substation can be further expanded through a secondary serial CAMAC high way loop if more than one crates are required. Several types of control substations have been constructed during system development period. In order to reduce the number of different subsystems, only two of them, the PC based and LSI-11 based CAMAC control substations are adopted for present system.

Accelerator equipments are divided into several subsystems. They are controlled either by normal serial CAMAC crates or by control substations.

The injection and extraction transport line and SSC magnet power supplies are all controlled by serial CAMAC crates which are directly connected to the main high way loop and controlled by the central computer.

RF system is controlled by a PC based CAMAC control substation composed of 8 CAMAC crates.

Vacuum system is monitored by another PC based CAMAC substation.

Beam diagnose system is controlled by a LSI-11 based CAMAC control substation composed of 4 CAMAC crates.

All equipments are connected to CAMAC modules via signal conditioner electronics which was developed by HIRFL.

2. Software system

The software of HIRFL control system has two levels. The main control programs for the central computer are all VMS tasks and

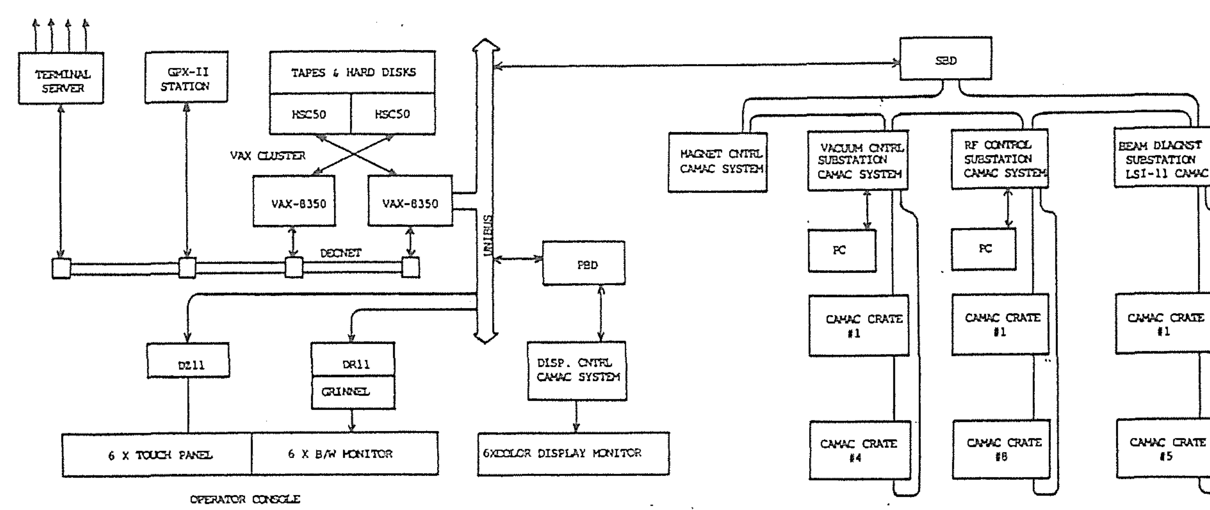

FIG.3 BLOCK DIAGRAM OF HIRFL CONTROL SYSTEM

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written in FORTRAN. They accept main console command, generate various displays and send control command and data to CAMAC crates or to the control substations.

Software for the substations were written with FORTRAN and BASIC languages. Menu type man-machine interfaces are implemented for convenience of operation. The substation control programs perform all the basic control functions: equipment parameter adjustment, on/off control, status monitoring and generation of local status displays.

3. Present Status

All the control substations were completed in 1988 and was in operation before the beginning of SSC commissioning. They have satisfied the requirement of HIRFL commissioning and operation.

A system composed of two 386 PCs and CAMAC systems were built for the SFC control recently.

The VAX cluster was installed in Jan. 1988. A VAX control program for SSC magnet power supply system is completed and in operation. Development of VAX central control programs for other subsystem is under way.

The next goal of HIRFL control group is to realize central control of all SSC and the SFC equipments.

IV. HESYRL CONTROL SYSTEM

HESYRL is a dedicated synchrotron radiation source designed for UV and X-ray experiments. The project started in 1984 and completed in 1989.

The main facilities of HESYRL are a 200 MeV electron linear accelerator, a beam transport line, and an 800 MeV electron storage ring. The control system are mainly divided into three relatively independent parts: a linac control system, a ring control system and a timing system.

1. System Configuration

The HESYRL ring control system is a distributed computer control system composed of a PDP11/45 computer, two 286 PCs, a communication microcomputer and up to 40 local control microcomputers(LCM). Fig. 4 is a block diagram of the ring control system.

Originally we plan to use a VAX11/780 as the main control computer. Both budget and delivery time problem led us to the choice of a PDP11/45 computer as a temporary alternative. Now because of the small memory size and poor display ability, its function is reduced to part of communication. Main control functions and console operation are all performed by the two PCs which are connected to serial ports of the PDP.

Ring equipments are controlled by local control microcomputers. Most of them are MULTIBUS system composed of a crate, a CPU board, a serial communication/memory expansion board and a several other interface boards. Because PCs are more convenient in programming and display we have also used some PCs as LCMs. The LCMs are located near the equipments. One LCM controls only one or one type of equipments.

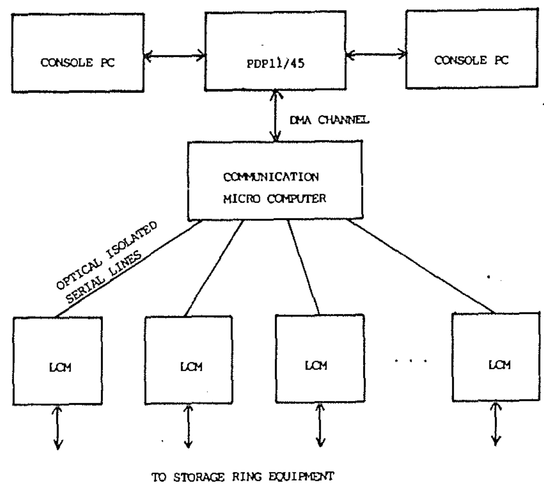

FIG. 4 BLOCK DIAGRAM OF HESYRL RING CONTROL SYSTEM

Because of the local intelligence of the LCMs, direct control and monitoring of the hardware equipments from the main computer are unnecessary. Most of operations are performed by the LCMs, system reliability and speed is improved. This is more obvious for ramping operation. With preloaded ramping table and hardware synchronization, ramping time can be less than 1 minute.

The CMM is a microcomputer specially designed for communication. It is a MULTIBUS system consists of a master CPU board, a DMA communication board and up to 10 intelligent serial communication board. CMM exchanges data with PDP through DMA channel and communicates with LCMs through serial links. Maximum number of channels is 40.

Low cost and convenient optical isolated asynchronous serial lines are used for data communication between the CMM and LCMs.

2. Software

The software for the control system consists of three levels: ROM monitor for the LCMs, communication program and ring control program.

ROM monitor of the LCM micros manages the LCM resources, handles communication and performs various control and monitoring functions.

The communication program includes ROM control monitor for the CMM, DR11-B driver and data buffer manager for the PDP.

The main function of CMM monitor is to handle the data exchange between the LCMs and the PDP. All data are exchanged in records. Error detection and retransmission are

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implemented.

The PDP DR11-B driver is installed as a device driver under the RSX11-M operating system and can be invoked by QIO. LCM status informations are stored in a shared data region on the PDP which is accessible by the console PC programs.

Ring control program includes transport line control, ring device status display, ring lattice setting and changing, beam energy ramping process control, close orbit correction and equipment testing programs.

Presently only transport line control, lattice setting, ramping control program and orbit correction programs are executed on the console PCs. Ring modeling, ramping table generation and other calculations are performed off-line.

3. Present status

The system was completed in March 1989 and has been operated since then. During the commissioning period the control system has performed satisfactorily.

Ring magnet control assured stable ring operation.

Ring control programs serve well for injection and ramping process control. But off-line calculation of physics parameters is inconvenient for machine study.

Beam energy ramping control is very successful. With the table ramping technique energy ramping or transfer to different lattice is very easy and smooth. Beam loss rate from 200 MeV to 800 MeV with 200 mA current is less than 7%. This is a good indication of ramping accuracy.

System communication has been reliable. But the response is slow. This is due to the speed of serial lines between console PCs and the PDP. LCMs are reliable and easy to maintain.

4. Upgrading plan

Several problems exist in the present HESYRL control system: 1) Transport line control and vacuum monitoring are now controlled by two standalone PC control system. They are not linked to the ring control system. This is not convenient for system management and data logging. 2) PDP seems unnecessary in the communication system, also it becomes a weak point. 3) Lack of on-line calculation ability is not desirable.

In order to solve the above problems, system improvements are planned.

DECNET will be implemented to link a Micro VAXII, the console PCs, transport line control PC, vacuum monitoring PC and a recently installed VAX6310 system together. This will give us a fully linked system with much expanded computing power.

The PDP computer will be replaced by two BIT3 bus connector cards which connect PC bus to MULTIBUS of the communication microcomputer. This will eliminate the bottle-neck and increase data speed of the whole system.

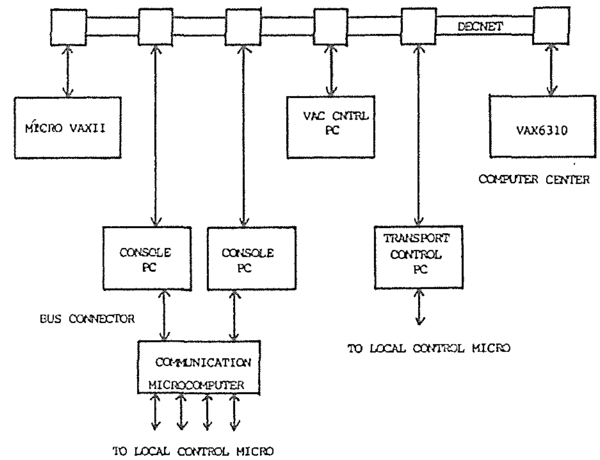

FIG.5 UPGRADE OF HESYRL CONTROL SYSTEM

Console display and computation power will be upgraded by replacing the console PCs with more powerful 386 or 486 stations.

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

V. CONCLUSION

Started almost in same period, the control systems of the three accelerators are now all in operation. In parallel with the development of the systems, our chinese colleagues have gained experiences and established their qualified cooperative teams. This is a promising start.

Compared with world advanced laboratories our systems are not advanced no matter in architecture, hardware or software. Some system upgrading and optimizing work remains to be carried out.

VI. ACKNOWLEDGMENT

During design and construction periods we have received great help from SLAC, NSLS, KEK, CERN and many other laboratories. we would like to take this opportunity to express our thanks.

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VII. REFERENCES

1. BEPC control group, The Status and Upgrade of BEPC Control System, BEPC workshop, June 1991, Beijing

2. T.S.Jiao, HIRFL Control System, Proc. of The Fourth Symposium of PASC