CONTROL SYSTEM OF JAERI AVF CYCLOTRON

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Abstract

The computer control system of the JAERI AVF cyclotron has been developed. This system is composed of a central computer serving man-machine interfaces, two subcomputers executing sequential device controls, and device controllers. The central computer and the subcomputers are linked through an Ethernet. A device controller is connected to a subcomputer by a signal-multiplexed communication system. To assist an operator, a knowledge based operation assist system has been developed. This system provides sequences of operation, beam trajectories, etc.

Introduction

The JAERI AVF cyclotron[1] has been constructed to accelerate many kinds of ions over a wide range of energies for materials science research. The computer control system of the cyclotron was designed so that an inexperienced operator can control it easily. An operator can turn the cyclotron on or off via a simplified operation through automated sequences and adjust parameters with rotary-encoders quickly.

The system is divided into three layers. The top layer provides the man-machine interface and manages lower layers. The middle layer executes the sequences of device groups. The bottom layer controls each component device.

The efficient beam production requires theoretical and empirical knowledges. To assist an operator with these knowledges, a knowledge based expert system and a beam trajectory simulation system have been developed.

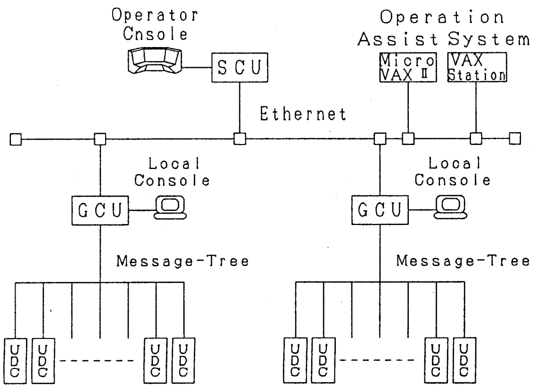

Fig. 1. Architecture of the control system

System architecture

Figure 1 shows an architecture of the control system. The system has a tree structure. In the top layer, a central computer named system control unit(SCU) controls the whole system and serve operators with many operational functions. In the middle layer, two subcomputers named group control unit(GCU) control groups of devices sequentially. In the bottom layer, many device controllers named universal device controller(UDC) are installed in each device for specific controls.

SCU, GCU's, the knowledge based expert system(Micro VAX II) and the beam trajectory simulation system(VAXstation 3100) are connected to each other through an Ethernet. GCU communicates with UDC's through a signal-multiplexed communication system named Message-Tree.

SCU

SCU comprises a central processing unit(Micro VAX 3500), two hard disks, and several interface devices. It provides the following functions:
- touch-screens, rotary-encoders, and graphic displays;
- command for automated sequences in GCU;
- management of database;
- system status displays and fault detection messages;
- calculation of device control parameters for a new beam condition;
- development of application software for SCU and GCU.
- communication with GCU through the Ethernet.

GCU

Two GCU's(rt VAX1000) execute sequential control for each group of devices by commands from SCU. All devices are divided into four groups: ion sources, the injection system, the cyclotron, and the beam transport system. One GCU manages the first three systems, and the other manages the beam transport system. They provide the following functions:
- sequential control for each group;
- fail-safe sequence for machine protection;
- local console for device control separately from SCU;
- communication with SCU through the Ethernet and with UDC's through Message-Tree's.

UDC

UDC is a single-board computer standardized for easy development and maintenance. Table 1 gives the specification of the UDC hardware. About 470 UDC's are used in this system. They provide the following functions:

- intelligent control for each device by using eight tasks(including communication task);
- optically isolated 32bit DI, 32bit DO and 16bit PIO;
- iSBX bus socket for additional iSBX bus interface board, such as RS232C, GPIB and analog IO;
- local panel for independent operation;
- communication with GCU through Message-Tree.

Table 1
Specification of the UDC hardware

MPU	i8344(Intel)
Clock frequency	12 MHz
Memory	16 kbyte ROM,
	32 kbyte ROM,
	32 kbyte RAM
Serial interface	SDLC 1port
	iSBX 1port
Board size	100mm × 220 mm(Euro card)
Connector	DIN41612(96pin)

Message-Tree

A Message-Tree consists of an interface board installed in the GCU, named message tree communicator(MTC), a signal distributor named message tree brancher(MTB) and UDC's. Fifty UDC's can be connected to a MTC by a Message-Tree.

Message-Tree is a polling-addressing communication system; a MTC is a master and UDC's are slaves. MTC receives order messages from GCU, and sends them to all UDC's through a MTB. UDC's receive the message identified with the UDC number and send only changed status messages for reducing communication loads. These communication are executed every 100 ms. Message-Tree provides following features:

- electromagnetic noise immunity by using optical-fiber cables;
- transmission speed of 375 kbit/s;
- transmission capability of 2.6 km;
- synchronous data-link control(SDLC) protocol.

Operation

Operator console

The cyclotron is normally operated by using an operator console in the control room, as shown in Fig.2. The operator console consists of a pair of identical control units, and a monitor unit composed of a monitor TV for beam diagnostics, a 400MHz oscilloscope for fast-signal measurement, etc. Each control unit provides a display-panel, an operation-panel, an adjustment-panel and the touch-screens on these panels. An operator can control devices by touching color-coded cells on the displays in combination with four rotary-encoders. The response time from the action to change parameter to the display of changed active parameter is about 250 ms. The cyclotron is Efficiently operated by using two control units simultaneously.

Operation procedure

In normal operation, an operator has to go through two operational steps; starting up devices and adjusting device parameters. The former step can be executed through auto-start mode which start up all devices sequentially. However, we use group-start mode which starts up devices in a group. The latter can be executed through operator's efforts to search for optimum condition. Without any care of running programs the operator can operate by touching cells on the displays in the following way:

(1) to select the beam condition such as the beam energy;
(2) to load the preset parameters into devices;
(3) to start up groups of devices;
(4) to assign a rotary-encoder for adjusting a device parameter;
(5) to adjust the parameter with turning the rotary-encoder.

When a fault occurs, a fail-safe sequence is executed automatically and alarm messages are displayed. An operator can receive informations on devices to clear up the causes of the fault.

Software

The operating system of SCU is VMS, and that of GCU is VAXELN, and C language is mainly used in these systems. The control programs and device information stored in SCU are loaded into GCU's at system start-up, since GCU has no magnetic-disk.

The control programs in GCU are described in a concurrent interpretive language for sequence control of accelerators, named OPELA(OPEration Language for Accelerator)[2]. This language has the following characteristics:

- the concurrent and synchronous execution of several sequences;
- easy debugs and modifications;
- fast execution by the intermediate language;
- linkage with the programs described in C language;
- process for asynchronous events;
- management of all devices by using the logical name.

The operating system of UDC(UDC44) has been developed for multitask programming to control devices. UDC44 consists of a kernel, a basic I/O system(BIOS) and a serial interface unit(SIU) handler. The kernel can manage eight tasks, and the BIOS manages communication registers and input-output ports. The SIU handler is a communication task for Message-Tree. Application programs can be written in a high-level language PL/M51.

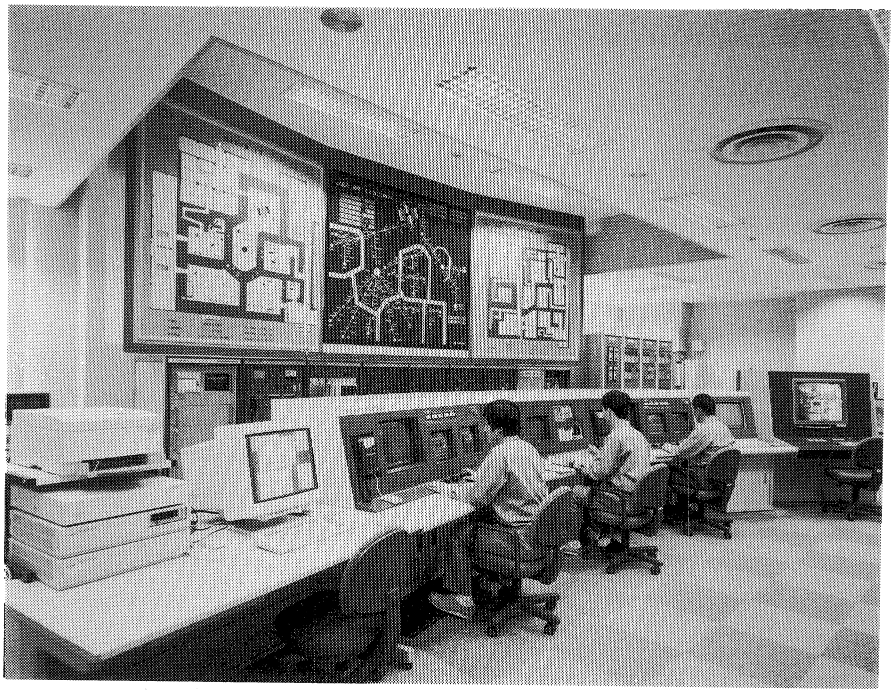

Fig.2. Control room of JAERI AVF cyclotron

Knowledge based operation assist system

Adjustment of cyclotron parameters requires a lot of theoretical and empirical knowledge. To provide operators with the knowledge a knowledge based expert system (Micro VAX II) and a beam trajectory simulation system (VAXstation 3100) have been developed.

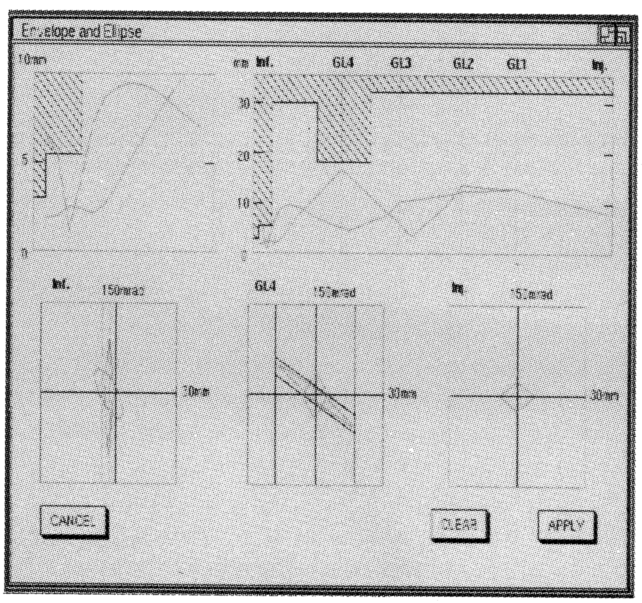

Fig.3. Simulation graphs of beam trajectories in axial injection

The knowledge based expert system provides the sequences of operation for parameter adjustment. These sequences can be used as on-line manual. The sequences of operation are divided into eight blocks from axial injection to extraction of the cyclotron, so that even an inexperienced operator can understand the sequences clearly. This system can be more powerful by acquiring the knowledges of operations from experienced operators.

The beam trajectory simulation system visualizes beam trajectories and correlations among parameters. Beam trajectories are calculated and displayed graphically for axial injection, central region and extraction of the cyclotron, whenever operators change cyclotron parameters. Allowable setting range of parameters that satisfies acceptance of the cyclotron is indicated on multi-dimensional graphs. Figure 3 shows example of simulation graphs.

References

1. K.Arakawa, et al., presented at this symposium.
2. K.Iso, et al., "A concurrent interpretive language for sequence control of accelerators", in proceedings of first workshop on control systems, Tsukuba, Japan, 1987, pp.100-103.