CONTROL SYSTEM FOR JAERI AVF CYCLOTRON

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ABSTRACT

The computer control system of the JAERI AVF cyclotron has been developed, and is now in operation. This system is a distributed computer system and is composed of a central computer serving man-machine interfaces, two subcomputers executing sequential device controls, and device controllers installed in each device. 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. One operator can easily control the cyclotron through this control system. To assist an operator, a knowledge based operation assist system has been developed. This system provides sequences of operation, simulated beam trajectories, etc.

1. INTRODUCTION

The JAERI AVF cyclotron[1)] has been constructed to accelerate many kinds of ions over a wide range of energies mainly for various fields of materials science research. It is required that beam condition can be changed rapidly and frequently for effective use of the cyclotron. The computer control system of the cyclotron was designed so that an operator can control devices smoothly without thinking about computers and programming. Using a man-machine interface and automated sequential programs, the operator can turn the cyclotron on or off and adjust device parameters efficiently. Such functions reduce the beam production time.

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

In the cyclotron operation, theoretical and empirical knowledge is required for efficient beam production. To assist an operator with this knowledge, an operation assist system has been developed.

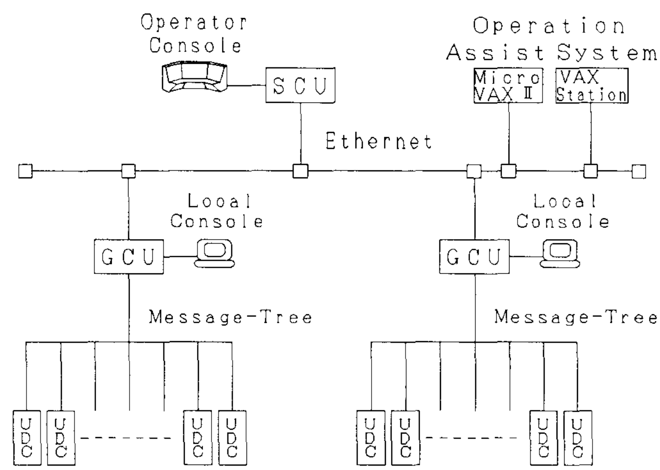

Fig. 1. Architecture of the JAERI AVF cyclotron control system

2. SYSTEM ARCHITECTURE

The system is composed of computer networks like a tree structure and is divided into three layers, as shown in Fig.1. In the top layer, a central computer named system control unit (SCU) manages the whole system and serves operators with man-machine interfaces and operation functions. In the middle layer, two subcomputers named group control unit (GCU) control groups of devices. In the bottom layer, universal device controller (UDC), single-board computers, are installed in each device for specific control.

SCU, GCU's and the operation assist system are connected to each other through an Ethernet. GCU communicates with UDC's through a signal-multiplexed communication system named Message-Tree.

2.1. System Control Unit (SCU)

SCU comprises a central processing unit (Micro VAX 3500), two hard disks, and several kinds of interface devices. Using touch-screens, rotary-encoders and graphic displays provided by SCU, the operator can control devices smoothly. SCU manages device conditions and control processes, communicating with GCU's. Various files such as program files and parameter files are stored and maintained in SCU. For a new beam production, SCU calculates a new set of parameters from stored parameter files of accelerated beams.

2.2. Group Control Unit (GCU)

Two GCU's (rt VAX1000) execute control sequences for each group of devices according to commands of 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 groups, and the other manages the last group through Message-Tree. Local consoles can connect with a GCU to control devices directly from GCU for construction and maintenance.

2.3. Universal Device Controller (UDC)

A UDC is an eight-bit single-board computer, as shown in Fig.2, standardized for easy development and maintenance. 420 UDC's are used in the whole system. Table 1 gives the specification of the UDC hardware. System and application software is programmed into two ROM's. A UDC controls each device intelligently through optically isolated 32-bit digital inputs, 32-bit digital output and 16-bit parallel input/output by executing up to eight tasks (including communication task). Devices can be operated directly using a local panel connected with UDC, as shown in Fig.3. The local panel indicates preset and actual values of the device, and provides several buttons for operation.

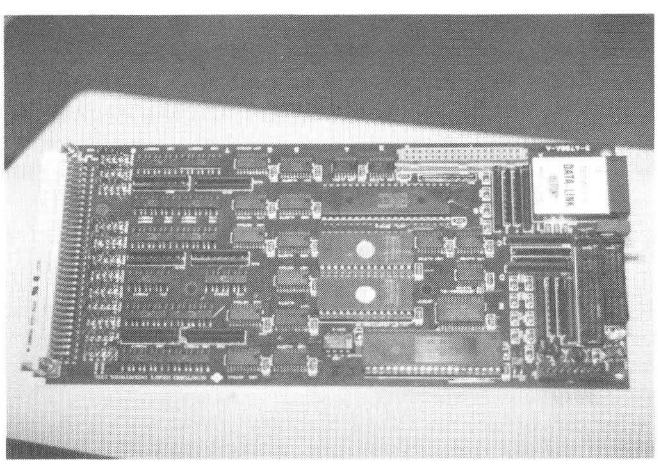

Fig. 2. Universal device controller (UDC)

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×220mm
	(Euro card)
Connector	DIN41612(96pin)

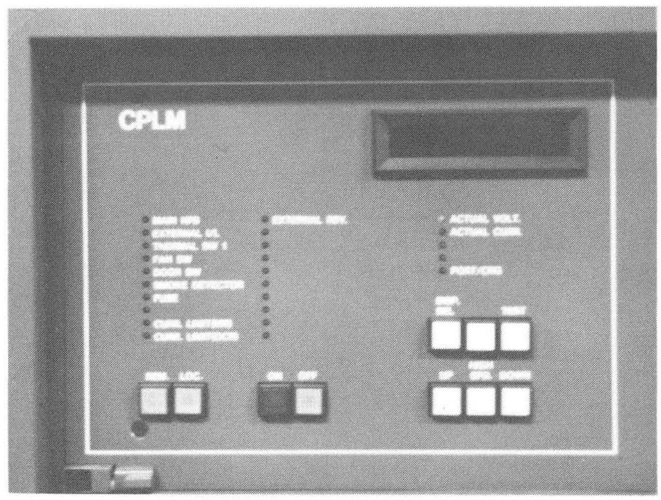

Fig. 3. Local panel of UDC

2.4. Message-Tree

A Message-Tree is a signal-multiplexed communication system between GCU and UDC's, and consists of an interface board installed in GCU, named message tree communicator (MTC), a signal distributor named message tree brancher (MTB) and UDC's, as shown in Fig.4. Fifty UDC's can be connected to a MTC through a Message-Tree, and five MTC's can be connected to a GCU.

Message-Tree is a polling-addressing communication system; an MTC is a master and UDC's are slaves. MTC sends order messages to all UDC's through an MTB. An MTB distributes the messages to all connected UDC's. UDC's receive the message identified by the UDC number and send response messages including only changed status data for reducing communication loads. These communications are executed every 100 ms. The major features of Message-Tree are the following:

- electromagnetic noise immunity by using optical-fiber cables;

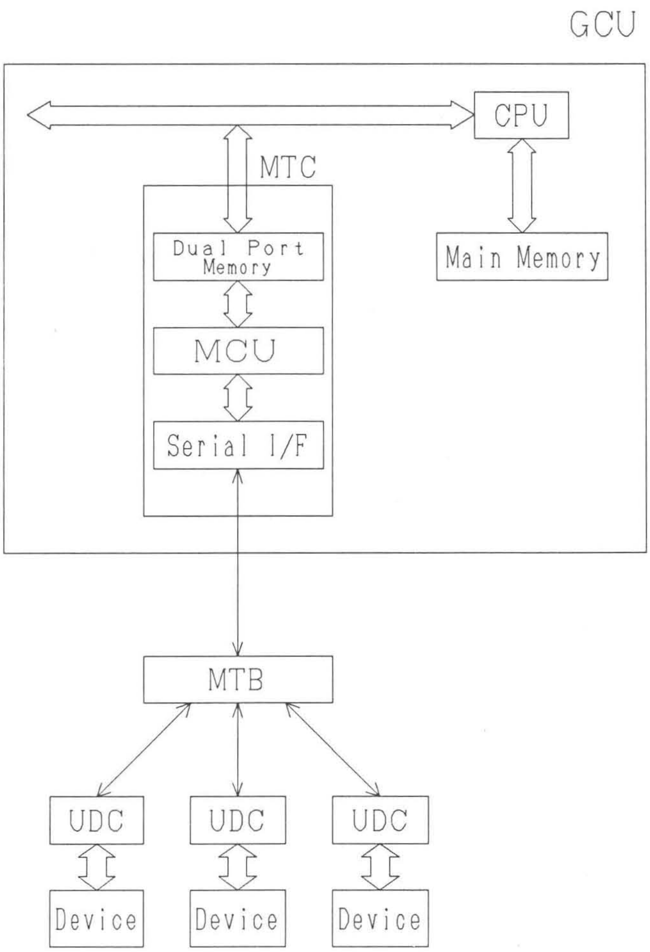

Fig. 4. Block diagram of Message-Tree

- transmission speed of 375 kbit/s;
- transmission capability of 2.6 km;
- synchronous data-link control(SDLC) protocol.

3. OPERATION

3.1. Operator Console

The cyclotron is normally operated using an operator console in the control room, as shown in Fig.5. The operator console consists of a pair of identical control units, and a monitor unit composed of a monitor TV for beam diagnostics, a 400 MHz oscilloscope for fast-signal measurement, etc. Each control unit provides a display-panel (20-inch CRT), an operation-panel (14-inch CRT), an adjustment-panel (14-inch CRT), the touch-screens on these panels, and four rotary-encoders, as shown in Fig.6. An operator can control devices by touching color-coded cells on the displays in combination with four

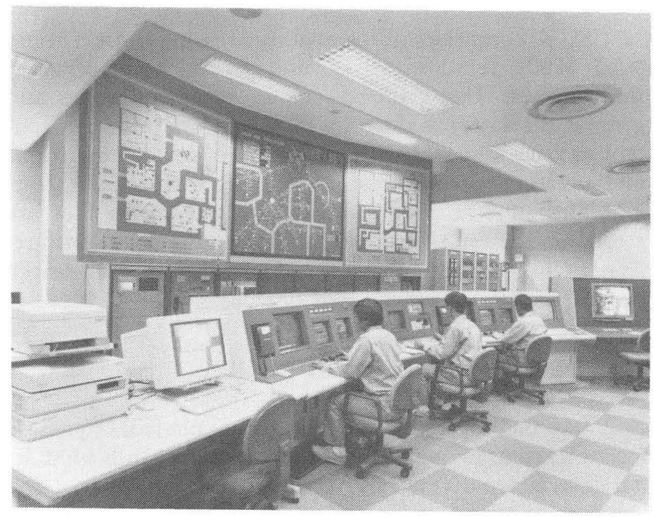

Fig. 5. Control room of the JAERI AVF cyclotron

Fig. 6. Control unit

rotary-encoders. The response time from a change of parameter to the display of changed actual parameter is about 250 ms. The cyclotron is operated efficiently using two control units simultaneously.

3.2. Operation Procedure

In normal operation, an operator has to go through two operational steps: starting up devices and adjusting device parameters. The former can be executed by auto- start mode starting up all devices sequentially. The latter can be accomplished through operator's efforts to search for the optimum condition. Without any care of running programs the operator can control devices by touching cells on the displays for the following ways:

1. selecting the beam condition such as the beam energy;

2. loading the preset parameters into devices;

3. starting up groups of devices;

4. assigning a rotary-encoder for adjusting a device parameter;

5. adjusting the parameter with turning the rotary-encoder.

When a fault occurs, a fail-safe sequence is executed automatically and the alarm is given in sound and display. An operator can receive information about the fault to clear up the causes.

Various data for every run of beam acceleration, such as ion species, acceleration energy and device parameters, are recorded in a log-file which is useful to refer records of past operations for next beam production.

4. SAFETY SYSTEM

An interlock system always monitors the status of devices and irradiation rooms to reject the wrong operation and to stop devices immediately whenever any failure occurs. To prevent serious failures, a hardware interlock composed of relay circuits is used in combination with software one. For more serious failures, an emergency switch which turns off the whole system was installed on the operator console. The beam current is always monitored so as not to exceed the limit of radiation safety.

To protect crews and visitors from accidents, the announcement with a public- address system and the display with graphic panel give them information about the status of the cyclotron, and the operator can watch the insides of target rooms through a monitor TV from the control room.

5. SOFTWARE

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

The programs for GCU are described in a concurrent interpretive language for sequence control of accelerators, named OPELA (OPEration Language for Accelerator).[2] Sequence programs are described in this language and executed concurrently. These programs can be debugged and modified easily and executed fast by using the intermediate codes. In these programs devices are treated by using logical names to set and refer to parameter values.

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.

6. OPERATION ASSIST SYSTEM

Adjustment of cyclotron parameters requires a lot of theoretical and empirical knowledge. To provide operators with the knowledge an operation assist system is developed. The system is composed of two systems: a knowledge based expert system (Micro VAX II) and a beam trajectory simulation system (VAXstation 3100).[3]

The knowledge based expert system is programed by OPS83. This system shows the operational sequences for parameter adjustment when operators need advice. These sequences, written in the IF-THEN form, are stored in the knowledge base and referred according to the operational condition. 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 knowledge 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.

7. REFERENCES

1) Arakawa, K., et al., "Construction and First Year's Operation of the JAERI AVF Cyclotron," presented at this conference.

2) Iso, K., et al., "A Concurrent Interpretive Language for Sequence Control of Accelerators", in **Proc. of First Workshop on Control Systems** (Tsukuba, Japan, 1987), pp.100–103.

3) Okamura, T., et al., "An Operation Assistance System for AVF Cyclotron", presented at this conference.