DESIGN OF DISTRIBUTED CONTROL SYSTEM FOR THE RCNP RING CYCLOTRON

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ABSTRACT

A distributed computer control system of the RCNP ring cyclotron has been designed. The control system consists of a computer network with a central computer, four computers, universal device controllers which control component devices, interlock systems and man-machine interfaces. The universal device controller is a small-size single board computer with 8344 micro-controller, parallel interfaces and a local panel interfaces, and is installed within each component devices. An optical communication system provides high speed data transmission capability. Control sequences of subsystems are easily modified and debugged by using an interpreter named OPELA (OPEration Language for Accelerators). The control system will be assembled in March, 1990.

1. INTRODUCTION

The RCNP ring cyclotron will use the AVF cyclotron[1] in operation as an injector. The control system of the AVF cyclotron is a digital control system using logic elements, and after operational experience of a few years it has been interfaced to a computer system. To construct new control system more efficiently, it has been decided that the control system of the AVF cyclotron is not modified or updated and it will be used manually. For the ring cyclotron a hierarchical computer control system is adopted, and the computer system of the AVF cyclotron will be used for data logging at the first stage of the operation of the cyclotron cascade.[2] The operator console of the ring cyclotron will be installed near the present operator console of the AVF cyclotron, and it is designed to operate both cyclotrons by single operator.

The first layer performs man-machine interface. The second layer controls subsystems such as magnets, RF systems or beam transport lines. The third layer controls each equipment.

Each equipment is handled by each logical name. By introducing an interpreter language for an accelerator controls to describe an operation sequence of each device, it makes easy constructions and modifications of the softwares.

Basic design of the control system was done in 1987. The detailed design has been almost completed in 1988. The control system is now in the step of construction. Some power supplies constructed in 1988 already contain an intelligent device controllers to allow local operation.

2. SYSTEM CONFIGURATION

The control system of the ring cyclotron and beam transport lines consists of three layer control units, which are a central computer (system control computer microVAX 3500) named SCU (System Control Unit), four sub-computers (group control computers microVAX II or RT VAX) named GCU (Group Control Unit), and device controllers. The control functions of the accelerator are distributed to five com-

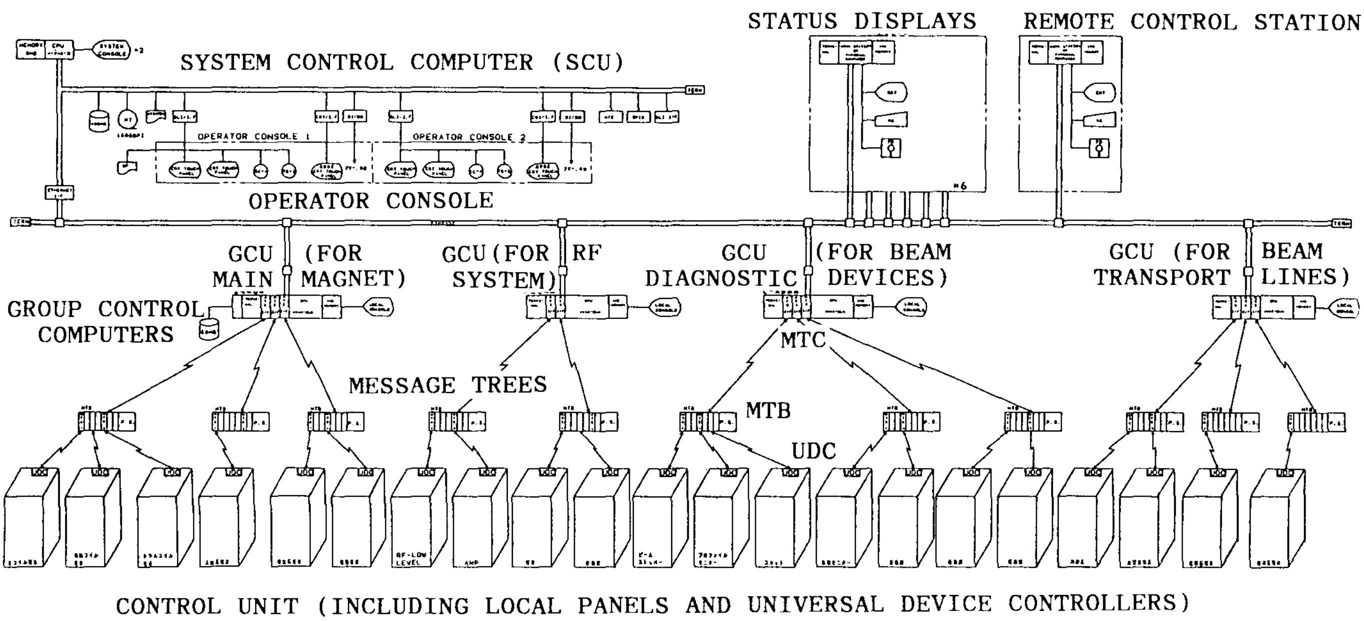

Fig. 1 control system of RCNP ring cyclotron puters and many intelligent device controllers. Each group control computer is connected to the system control computer through a computer network Ethernet. Each group control computer is also connected to many device controllers by an optical communication system. Fig. 1 shows the schematic diagram of control system.

The system control computer has charge of a concentrated control of the total system and a man-machine interface. The system control computer controls to start-up and to shut-down the operations of the devices, to maintain operation parameters, and to execute a man-machine interface through an operator console. The system control computer also manages operation parameters as a database to make easy parameter settings and adjustments.

The group control computers are used for the controls of cyclotron magnets, RF systems, beam diagnostic devices and beam transport lines including vacuum systems and cooling systems, respectively. The group control computers have charge of a general control of group such as a magnet system including beam injection and extraction devices, RF systems, beam diagnostic devices and beam transport lines. The control functions of group control computers are divided into two classes that are common to all group control computers and peculiar to individual computers. The functions common to all group control computers are the sequence controls of device group under instruction from the system control computer, command analyses and executions that are sent from the system control computer, the control of device controllers by sending parameter values to set-up, a man-machine interface between a local console of the computers and communications between other computers linked by the local area network. The functions peculiar to individual computers are the controls and the data handling of the devices contained in that group. The group control computer systems have no magnetic disk, and programs and device data are downlineloaded from the system control computer through the computer network at the starting time of the whole control system.

3. COMMUNICATION BETWEEN GROUP CONTROL COMPUTER AND DEVICE CONTROLLERS

To control power supplies and motor drived devices of the cyclotron and beam transport lines, a device controller is used in each device. These device controllers are linked to a sub-computer through optical fiber cables, and constitute a distributed control network.

This signal-multiplexed communication system named a message tree has been developed especially for accelerators. The message tree is made of an interface board installed in the group control computer named a message tree communicator (MTC), a branch device of the communication signal named a message tree brancher (MTB) and a controller installed in many devices named a universal device controller (UDC). Each universal device controller is connected to the message tree brancher in a tree configuration.

The group control computer writes data to a dual port memory. The message tree communicator formats these data for the communication, converts them to light signals and sends them to the message tree brancher. The message tree brancher distributes the data to all universal device controllers. The universal device controllers which constitute one message tree have their own identification numbers, and each universal controller takes the communication packet data which address is equal to its own identification number. The data received by the universal device controller have a command from the group control computer. The universal device controller analyses this command and returns a response. This response is received by the message tree communicator through the message tree brancher, and is written into the dual port memory. The message tree communicator executes the above procedure for all universal device controllers within the message tree, and after the series of processes the group control computer reads the data from the dual port memory.

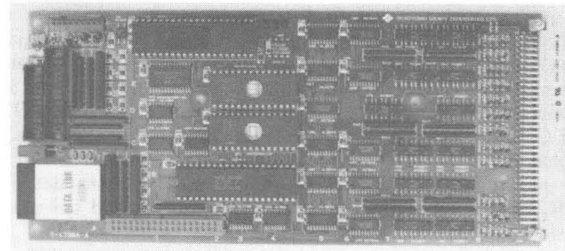

Fig. 2 UDC (Universal Device Controller) board

The communication data between the group control computer and the universal device controllers are stored in memory of each universal device controller named a communication register (CRG). The group control unit has images of communication registers in its memory. To minimize the communication load of the message tree, the universal device controller sends only modified data after previous communication to the message tree communicator.

4. UNIVERSAL DEVICE CONTROLLER UDC

For the easiness of maintenance of the control components interfaces to devices are standardized. For these purposes a universal device controller has been developed. Fig. 2 shows a universal device controller board.

4.1 Basic Function of UDC

The basic functions of the universal device controller are as follows.

The functions common to all universal device controller are the communications to the group control computer and the status displays at the local panels connected to each universal device controller. In the power supplies of magnets, high voltage electrodes and RF systems, the universal device controllers are used for the periodic data accumulations, sequence controls among the power supplies, interlock checks among the power supplies, switching of polarities and loads of power supplies, slow speed controls of currents and voltages using a preset time constant based on a preset values of currents and voltages, and their stability checks.

In the motor drived devices, the universal device controllers are used for the periodic data acquisitions, stability checks, the comparisons between the preset values and measured actual values and switching of driving speed. In the beam diagnostic devices, the universal device controllers are used for the control of the interlock sequence, and data acqusitions of beam currents. In the RF systems, the vacuum systems and the cooling systems the universal device controllers are used for the periodic data acquititions, the sequence control, and the interlock checks among the device groups.

4.2 Hardware of UDC

Each universal device controller contains an eight-bit microcomputer chip 8344, IC memories (16 Kbyte ROM and 8 Kbyte RAM) and related interface chips, and it is intended to reduce the computing load of the group control computer.

For the interfaces to devices, 32-bit digital inputs and 32-bit digital outputs are prepared. Moreover 16-bit bidirectional process input-outputs can be used as inputs or outputs. The universal device controller has an Intel iSBX bus, and it is possible to connect iSBX module boards such as ADC, DAC and GPIB. The universal device controller can also connect a local panel for the independent operation of each device, the maintenance of a device and universal device controller itself, switches used in the local adjustments, and the status displays.

4.3 Software of UDC

The universal device controller is one component of a distributed control network, the message tree. The universal device controller must execute many tasks such as device controls, communications with the message tree communicator, and interfaces with the local operator in real time.

For these purposes real-time multitask monitor UDC44 has been developed. Programs to control individual devices can be described by PL/M language. The UDC44 can execute task controls and input-output managements by issuing system calls. The UDC44 is constituted by kernel, BIOS and SIU handler. The kernel can manage up to eight tasks including SIU handler. The BIOS (basic input-output system) manages communication registers and input-output ports. The SIU handler manages data communication of message tree, and starts by receiving data.

The message tree constitutes multipoint semiduplex configuration. The message tree communicator is the primary station and universal device controllers are the secondary stations. The primary station (MTC) always sends a command to the secondary station (UDC), and then the secondary stations send responces to the primary station. The transmission protocol of the message tree is synchronous data link control (SDLC).

4.4 Control Unit and Local Panel

The universal device controller, interface boards, interlock relay boards and local panels are installed in a control unit. This control unit is installed in a cabinet of a power supply or control modules of driving motors. To avoid the radiation damage of the universal device controller boards, it is planned to install them far from the cyclotron vault.

Fig. 3 shows a local unit for the main coil power supply. This control unit contains a common local panel and only one individual panel. Some power supply such as quadrupole magnet power supply can control many magnet currents, and many control units are installed in the cabinet of the power supply. The first control unit can install common local panel, up to three individual local panels and up to three universal device controllers. The second and subsequent control units have no common local panel, and can install up to four individual local panels and up to four universal device controllers.

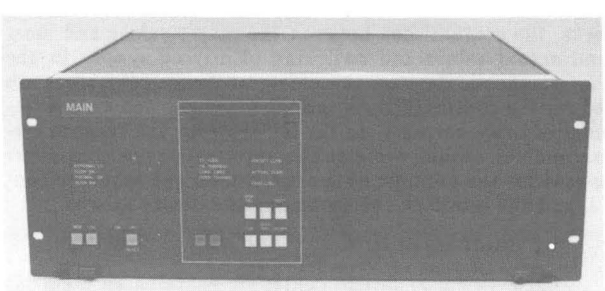

Fig. 3 local unit for the main coil power supply

The control programs constitute setting value output task, sequence control task and man-machine interface task. These tasks execute parameter changes for the setting values of power supply, alarm display, status and data display of communication registers and input-output ports, the monitoring of stability of power supplies and device interlocks.

5. OPERATOR CONSOLE

The operator console consists of two console units and analog signal display area. Two console units are entirely identical, and two operators can adjust devices independently.

5.1 Digital Control System

Each console unit has one 20-inch CRT display device with a touch screen and two 14-inch CRT displays with touch screens. The present status of many control components is displayed on the 20-inch color display device. One of 14-inch CRT display devices is used for a device selection, and the other is used for the adjustment of device parameters. For the parameter adjustments of devices four rotary encoders and two tracking balls are used. There are also eight general purpose color TV monitors.

The rotary encoders, the tracking balls and the touch screens are connected to the system control computer through RS232C serial interfaces. Large 20-inch color CRT display devices are connected to the system control computer through parallel interfaces, and enables rapid representations of graphic drawings and image processings. The 14-inch color CRT display devices are connected to the system control computer through character VRAM.

5.2 TV Monitors and Analog Data

The TV monitors display various images from many TV cameras located in the cyclotron vault, the beam transport lines and the experimental areas. The TV cameras are used to watch the present conditions inside the rooms where the radiation is in high level and the rooms of power supplies and cooling system. The TV cameras are also used together with a beam diagnostic device and to observe the beam profiles in the ring cyclotrons and the beam transport lines.

Although the status informations and analog signals from the control components are acquired by using the computer system, it is still necesary to handle analog data at the operator console. For these purposes eight beam amperemeters and digital oscilloscopes can be used. They are effective to observe the rapid change of signals without additional time delay originated from the computers. The digital oscilloscope is also used as an input device through its GPIB interface to the system control computer. The operator can observe signals from RF system and also beam profile signals from beam profile monitors located inside the ring cyclotron. A digital oscilloscope is also used to observe the high frequency signals from the beam phase monitors located in the cyclotron, beam injection system and extraction system.

5.3 Status Display

The operator console of the ring cyclotron will be installed in the control room of present AVF cyclotron. In front of the operator console of the AVF cyclotron, there exist status display panels of the AVF cyclotron, the beam transport lines, vacuum systems and cooling systems. These panels are very useful to monitor the accelerator status at a glance for not only the cyclotron operator on duty but also cyclotron crews off duty and even for visitors to the control room. Therefore these status display units are also necessary in new control system of the ring cyclotron.

New operator console can display the accelerator status, but the number of the display units on the operator console is limited. If an operator wants to monitor the status of accelerator, beam transport lines, vacuum systems and cooling systems simultaneously, the operator must select each item one after the other. To avoid these cumbersome operations, it is preferable to prepare some kinds of display panels near the operator console. For this purpose six sets of personal computers with color display units are used. These personal computers are linked to the system control computer through the Ethernet network, and display the global status of the ring cyclotron, beam transport lines, vacuum systems and cooling systems.

5.4 Remote Control Station

An experimental counting area is located far from the operator console area. When users of beam course enter into an experimental room, it is necessary to stop beam before the experimental room and to close rotary shutter of beam line within wall between the experimental room and the cyclotron vault. In ordet to execute these restricted operations by the users of beam course under close contact with cyclotron operator, some remote control computers connected to the system control computer will be installed in the experimental counting area.

Coil currents of some magnets of beam transport lines in experimental rooms must be changed according to individual experimental conditions. The control privilege of devices can be transferred from the system control computer to a remote control computer. A list of these device names must be registered in the system control computer for this purpose. At first parameter settings of beam transport devices are performed by an operator from the operator console through the system control computer and a group control computer. Then users of a beam course can adjust some predetermined kinds of device parameters within a limited parameter range from the experimental counting area.

6. OPERATION MODES

The devices are classified into groups depending on their control functions. Examples of the "groups" are the main magnet and RF systems. The devices of each group are divided into blocks depending on their control sequences. An example of the "blocks" is same kind of power supplies or driving motors contained in acceleration cavities.

The ring cyclotron can be operated with following three modes.

6.1 Operation at Local Panel

This mode may be used in course of construction and maintenance of the ring cyclotron. The universal device controller has a remote/local data bit in the communication registers, and the system control computer can know the status of individual device.

6.2 Operation at Group Control Computer

In normal operation of the control system the terminal of the group control computer is not necessary. However, by using this mode it is possible to operate particular subsystem independently. It is expected necessary in the course of construction and a shut-down of the system control computer. To provide against the trouble of the system control computer, one group control computer has a magnetic disk as a preparatory system disk. In the construction step, this group control computer with a magnetic disk will be dedicated for magnetic field measurement of the ring cyclotron magnets.

Control functions are distributed to the system control computer, the group control computers and the universal device controllers. Therefore, for example some data updates contained within the memory of the group control computers cannot be performed from the operator console or a system console terminal of the system control computer. Sometimes it is necessary to access to the console terminal of the group control computer directly. For this purpose it is planned to have remote terminals of the group control compters by switching from the console terminals.

6.3 Operation at Operator Console

The operations from the operator console consist of four modes. They are individual device operation of power supplies and motor drived devices, operation in unit of a block, operation in unit of a group, and operation of the whole system as one unit.

An automatic start-up of the whole system is not planned. Assuming that an operator always interrups the control sequence and confirms the related security whenever the high voltages of RF systems and electric channels of injection-extraction systems are applied, a control operation in unit of a block is natural.

7. CONTROL SOFTWARE

The operating system of the system control computer is VMS, and that of the group control computer is VAXELN. The programming language used in the system control computer and the group control computers is C language, and it is intended to have common program modules between computers.

Software files including source program files, listing files, application files and data files are collectively managed in the system control computer, and the effectiveness of program development and maintenance is also intended. The programs developed in the system control computer are down-line loaded to each group control computer through DECnet.

7.1 Touch Screen Operation

The man-machine interface system is based on the operations on touch screens. The picture layouts especially layouts of the touch screens are realized not by the procedure in each program but by the independent picture attribute tables and files. Interpretation and display of input informations are executed by referring these tables. By modifying attribute tables during the execution time, the modifications of the display contents are possible. Picture layouts can be prepared by editing picture attribute files by using related utility programs.

7.2 User Defined Picture Layout

Picture layouts are described by the picture attribute files which are independent from user tasks. Basic procedures relating to the picture exchange and the modifications of attribute and display contents are prepared as runtime libraries. Individual area of the display panel is open to application programs. Each task can draw on the display panel directly by using graphic libraries.

7.3 Hierarchy of Tasks

To make easy for a system modification and a program addition after the completion of a system, tasks are classified to two levels of basic tasks and application tasks.

The basic tasks are constituted by picture management task, touch screen management and communication management task group. They are basic task group to execute basic functions of the system. A modification of basic tasks between the individual system is expected to be little.

The application tasks such as individual picture display tasks and control tasks are updated very often for individual system. User programs added after system completion are included in the application tasks. Application tasks realize application dependent functions by using the functions of the basic tasks.

7.4 Parameter File

The system control computer manages and saves parameter files for the parameter settings on the system operations. By using a parameter selection function on the operator console, operation parameters are loaded from parameter files in the disk to the system control computer, the group control computers and the universal device controllers.

8. OPERATION LANGUAGE FOR ACCELERATORS OPELA

The devices that constitute accelerator can be classified by group (unit that can operate independently as subsystem) and block (unit that can operate independently by devices constituted within group). There exsist some independent sequences for each group and each block. To describe these sequences of accelerator operation, a sequence description language OPELA (OPeration Language for Accelerators) has been developed.

The OPELA language has following characteristics. By the execution of many sequences with concurrency each other, it is possible to describe hierarchical sequence and concurrent sequence. By adopting interpreter method, there become easier to debug and to modify the sequence. The OPELA is a BASIC-like language having intermediate language. It is possible to link the programs written by higher level languages. In order to describe the sequence more easily, a logical name called "operation name" corresponding to each device has been introduced. Device status and parameters can be referred by using operation names. By introducing the values to individual operation name, it is possible to set parameters or to drive device.

When one accesses to device by using operation name, one accesses indirectly to the device interface through an index table called "operation name table". By adopting this access method operation procedure to each device can be standardized. The operation name table is an array data containing detailed informations for each device such as address, upper and lower limit values for setting parameters. If one writes the control sequence by OPELA language and writes the detailed information for each device into the operation name table, it is possible to separate the sequence from the device attribute. Therefore it is possible to modify the detailed information during execution time without modifying sequence program. Then it becomes possible to add, to modify and to delete devices in runtime.

9. CONCLUSION

A standardized interface, the universal device controller UDC, has been developed. The control functions are distributed to the group control computers and the universal device controllers, and simultaneous adjustment and operation become possible. For the communications between the group control computer and the universal device controllers a message tree has been developed. For the sequence controls of devices OPELA language has been developed. Some universal device controllers have been installed in the cabinet of magnet coil and RF power supplies. The communication formats for beam diagnostic devices have been determined. The control system will be completed in 1990.

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