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Control system of a high energy beam transport system of HIMAC

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Abstract

The control system of the high energy beam transport system of HIMAC consists of a UNIX computer and a large scale interface system. Lengthy procedures, such as start-up or shutdown all the devices, can be done by only one command followed by sequential procedures in the interface system. Man-machine interface is concentrated on a console to operate easily. Total system eventually realizes the simplified operation and highly reliable performance. In this system, however, a special operation is required because of radiotherapy.

Introduction

The Heavy Ion Medical Accelerator in Chiba (HIMAC) is a complex of an injector linac cascade, two synchrotron rings, a high energy beam transport system and an irradiation system^{1,2}. Each system is called sub-system, and is controllable independently. Another computer system, a supervisor system, is monitoring all the sub-systems, and also working as an interface between the sub-systems.

Beams extracted from the rings are transported to four irradiation ports of three therapy rooms, and three experiment ports through the high energy beam transport (HEBT) lines. The constituents of the HEBT system are 16 bending magnets, 69 quadrupole magnets, 39 steering magnets, their power supplies including those for the suppression coils for residual magnetic field and correction coils, 30 beam monitors, 16 vacuum units, 16 NMR sets and many other devices. The HEBT control system was required to have functions of simplified and rapid operation of the devices, software interlocks to keep patients safe and highly reliable performance because of a medical machine. The medical use also requires a special operation related with beam irradiation for treatment. In this paper, features of the system and its operation are reported.

The HEBT control system

The control system is divided into the main com-

puter system and the interface system as shown in Fig.1. MELCOM70-MX5700II (Mitsubishi Electric Corporation) is in use as the main computer. The interface system, called MELTAC-RIO system, connects the computer and most devices of the HEBT. The computer has other interface ports of GPIB and PIO. GPIB and PIO are used for communication with NMR devices and with an interlock system, respectively. There are two sets of console as man-machine interface. These consoles are corresponding to beam lines from the upper and lower rings, respectively. Each console has 20" and 14" displays, and 3 rotary encoders. The displays are equipped with touch-panels. The computer system is connected to the supervisor system with LAN (Ethernet). Radiation dose is monitored not only at the irradiation control room but also on the consoles of the HEBT system through a LAN installed exclusively for monitoring the dose.

The interface system, MELTAC-RIO, consists of a communication unit and a group of distributed remote I/O (RIO) units. The communication unit works to arrange and manage data flow from the computer to RIO, and vice versa. Data from RIO is reformatted to be transmitted to the computer cyclically in every 200msec interval. The transmission cycle of 200msec is enough fast to monitor the system status. The computer interrupts the communication unit to send the commands (IT-message) to operate the devices. The computer can also send a file including parameters such as maximum and minimum currents, and repetition number for initialization, thus complicated procedure can be handled. The communication unit is connected to the computer with a data bus, MDWS-60.

Ten RIO units are distributed in this system as shown in Fig.1. Each unit is connected to various devices through three kinds of data bus, PIO or MELSECNET or I/O bus. The PIO connects the magnet power supplies and the relevant RIO units. DI and DO cards mounted in the units receive and transmit digital signals based on contacts or open collectors. In order to initialize the magnets, the RIO units sequentially control

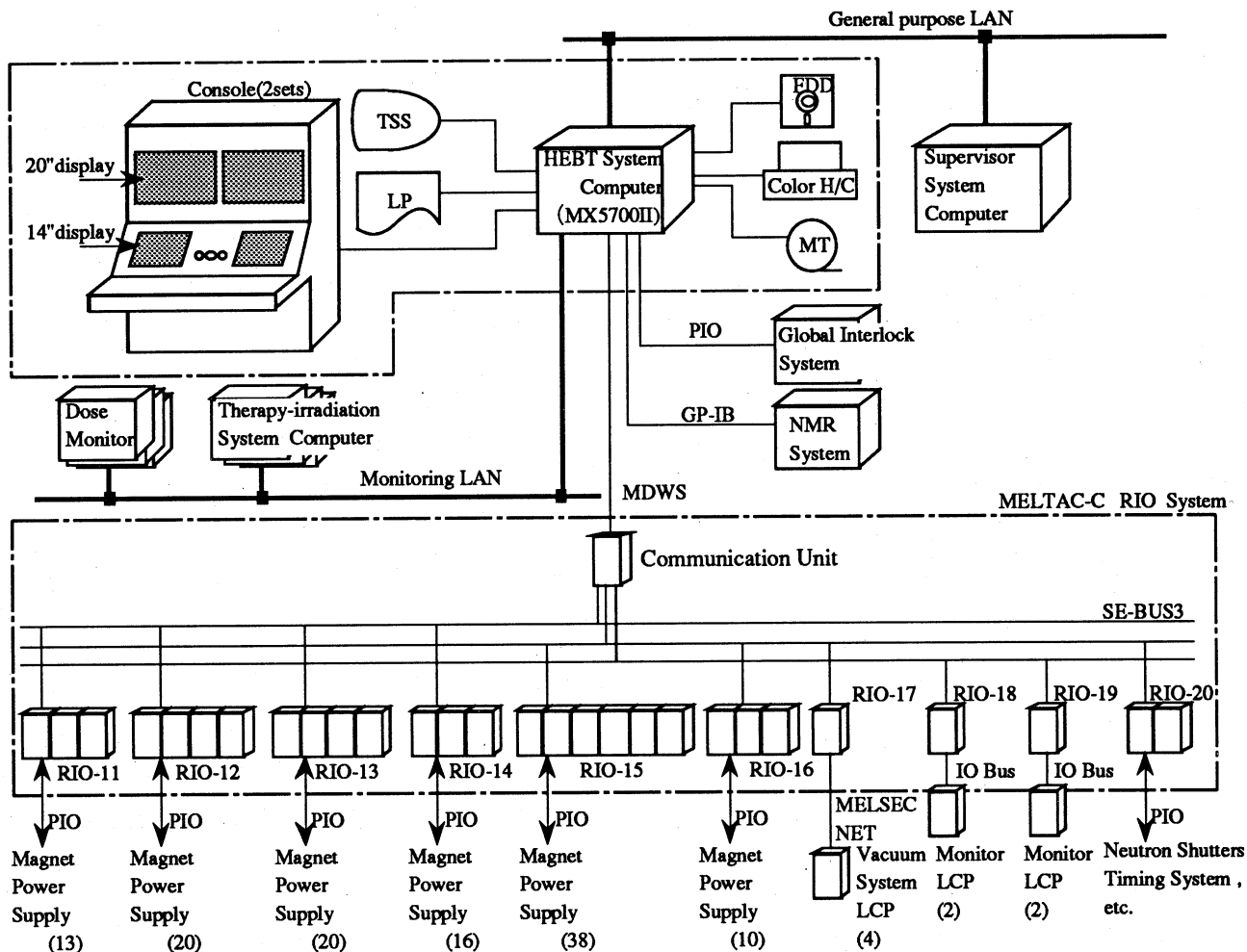


Fig.1 Schematic diagram of the HEBT control system

the power supplies according to the parameters of the initialization as mentioned above. Maximum 30 magnets can be initialized at the same time by only one command. Therefore, an arbitrary number of magnets can be initialized in short time by repeating the command. Local control panels (LCP) are distributed on the floor of the beam lines for the operation of the beam monitors and vacuum system, because it is necessary that the beam monitors and the vacuum system are locally operated in their maintenance. The devices of the vacuum system are controlled by a programmable logic controller (PLC) installed in a LCP. Four LCP's are linked in a circle, and the master LCP is connected to the RIO unit with the MELSECNET. The MELSECNET is exclusively designed for communication of the PLC. In case of the beam monitors, the DI and DO cards and buffer memories are mounted in the LCP's, not in the RIO units. Only

master cards are installed in the RIO units to communicate with the LCP's through the I/O bus.

This MELTAC-RIO system deals with a large amount of data such as magnet currents, magnet status, pressure in beam ducts, beam profiles, and of operation information such as power supply ON/OFF commands, magnet initialization commands and so on. In order to realize rapid operation and monitoring, this system are cyclically processing data under a single task software using cpu's of i-80386. The cycle runs every 100msec interval in the communication unit, and 50-70msec in the RIO units. The data is transmitted between the RIO units and the communication unit cyclically through data buses, called SE-BUS3. There are three groups of the SE-BUS3, in order to reduce the amount of data of each data bus, and realize a rapid response. The data buses are summarized in Table 1, all of them being Mitsubishi

Table 1 Summary of Data Bus

Data Bus	MDWS-60	SE-BUS 3	MELSECNET	I/O BUS
Medium of Transmission	Coaxial cables	Optical fiber cables	Optical fiber cables	Optical fiber cables
Transfer Rate	15.36Mbps	2Mbps	1.25Mbps	1Mbps
Method of Transmission	Cyclic File IT-Message	Cyclic	Cyclic	Polling/ Selecting Method

Electric Corporation standard. Note that the cyclic data process and data transmission can make a maximum load of the computer independent of the amount of data, and realize stable and reliable performance.

Operation and control

Beam tunings for the horizontal or vertical course can be done independently at each console. The devices of the HEBT system are hierarchically classified with "systems", "groups" and "blocks", as in other sub-systems³⁾. A block unit uniquely corresponds to a beam course. So the block classification makes it easy to switch the beam course from one to another.

The operation of starting up the whole HEBT system for new beam conditions is performed with the help of an operation parameter file. The file includes the setting values such as excitation currents of the magnets, high voltage of the beam monitors. In this operation, the magnets are initialized before excitation, and the beam monitors become ready to use by being applied suitable voltage. In about five minutes, devices are ready after the operation. Then a beam course is selected before tuning beam. Beam tuning is done for all the beam courses connected to the scheduled therapy rooms in advance of the treatments. It takes about 25 minutes for relevant beam course. Since the beam course selection is carried out by only exciting the switching magnets, the therapy room can be changed by only switching the beam course in 5-7 minutes.

Only medical operators are allowed to open the beam shutters in clinical patients irradiation. On the other hand, operators of the accelerator must handle the shutters to tune the beam. In order to prevent wrong operations, we allow opening the shutters from one console at a time, either HEBT or irradiation console. Both control systems can always close the beam shutters. Furthermore, the operators of either control system can

command not to change any operation parameters of upstream sub-systems during the treatments.

Software interlocks close or prohibit from opening the beam shutters under a few conditions of the HEBT system, in order to prevent unwanted irradiation of beams. The conditions are as follows. (1)No beam course is selected. (2)Magnets and/or power supplies of the selected beam course are out of normal conditions. (3)Any gate valve of the beam course is close. (4)The computer or the supervisor system does not work. (5)The computer is disconnected from the supervisor system. Therefore the software interlocks exclude wrong operations or abnormal conditions of the HEBT system.

Summary

In the HEBT control system, a large scale interface system, and its single task processes realize simplified and rapid operation with stable performance. All the operation functions are put together on the displays equipped with touch-panels and the rotary encoders as man-machine interfaces. These features make the operators possible to operate easily and uniformly. The software interlocks are excluding wrong operations due to human errors or machine failures. Overall the HEBT control system is reliable and easy to handle, and shows good performance.

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