Present Status of Device Controls and Hardware Interfaces for the RCNP Ring Cyclotron

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Abstract

Since the first proton beam from the injector AVF cyclotron was injected to the ring cyclotron in 1991, the computer control system has been used for the beam acceleration of the ring cyclotron. Some device control modules have been updated, and computer configuration has been changed in 1992. Total control system performs basic facilities almost satisfactory under actual cyclotron operation.

I. INTRODUCTION

The control system for the RCNP ring cyclotron was designed in 1987, [1,2,3] and the constructions of control hardware units and softwares were completed in 1990. Total control system was installed in the ring cyclotron building in 1990, and adjustments and operational tests of devices were executed from the local control panels connected to the universal device controllers located near the devices.[4]

The universal device controllers are connected to subcomputers with optical fiber cables, and the subcomputers are connected to the main computer with an Ethernet cable. Total control system was operated from the console displays of subcomputers and the central operator console connected to the main computer. The hardwired interlock sequences, the control sequences of startup-shutdown-fault processes stored in subcomputers, and databases that describes many characteristics of control items were updated based on valuable experiences of actual operations under various conditions.

Proton beam from the injector AVF cyclotron was injected to the ring cyclotron and accelerated in 1991. The computer control system is now used under almost satisfactory conditions for the beam acceleration of the ring cyclotron.[5]

II. CONTROL COMPUTER NETWORK

The computer network of the control system of the RCNP ring cyclotron and associated beam lines started with a main computer (a system control unit SCU using micro VAX 3500 computer with main memory of 16 M bytes) and four subcomputers (group control units GCUs using a micro VAX II computer and three diskless RTVAX 1000 computers with main memory of 9 M bytes).

The control program in the SCU main computer consists of 30 tasks. One task initiates another task or perfoms each operation by receiving adequate mails (requests or data) from other tasks. Rapid operations of the central operator console may generate many mails in a short time, and sometimes the number of mails becomes overflow. A combination of mails requires that many tasks must be resident in the main memory at the same time. If the capacity of the main memory is insufficient, frequent swappings of tasks may occur. This reduces the computer performance, and at last the control system becomes to hang up. To overcome this situation a system tuning of the operating system was tried. In 1992 the SCU main computer was replaced VAX 4000/200 computer with main memory of 48 M bytes. The system become stable since and the control-system hangup seldom occurs.

By communicating with 94 UDCs (universal device controllers) the RING-GCU subcomputer covers the controls of injection beam line, cyclotron magnets and injection-extraction system. By communicating with 98 UDCs the BT-GCU subcomputer covers the controls of magnets of the beam line. By communicating with 59 UDCs the DIAG-GCU subcomputer covers the control of beam diagnostic devices. The RF-GCU subcomputer covered the controls of RF system, vacuum system and cooling system, and this GCU subcomputer communicated with many UDCs (i.e. 182 UDCs). New VACCOL-GCU subcomputer was added to cover the controls of vacuum system and cooling system by communicating with 84 UDCs. Consequently the RF-GCU subcomputer now covers the controls of RF system including beam buncher located in the injection beam line, and communicates with 98 UDCs. Now two micro VAX II computers are used as RING- and RF-GCU, and three RTVAX 1000 computers are used as VACCOL-, BT- and DIAG-GCU.

III. UNIVERSAL DEVICE CONTROLLER

During long-time operation of the ring cyclotron some UDCs become to unable to control from the SCU main computer and central operator console. This phenomena occur only for UDCs installed on the basement of the ring cyclotron vault. For example, the UDCs for the controls of power supplies of trim coils and phase-voltage tuning controls of the accelerating cavities of RF system become to uncontrollable. By resetting UDC board manually in the cyclotron vault this UDC becomes to controllable from the main computer again. Lines on the UDC boards seem to suffer from a kind of noise created nearby. By adding noise artificially to a UDC board one can reproduce similar phenomena and this noise seems at least one of the origins. The processor chip on the UDC is Intel 8344 microcontroller and has 192-byte dual-port RAM on the chip. After examining the ROM firmware of the UDC some data areas were moved from external RAM to internal RAM. If the noise disturbes the signal around the processor chip, this countermeasure may reduce the hangup of the UDCs.

After replacing the firmware ROM chips of UDCs in the cyclotron vault with revised ones the hangup of the UDCs is avoided.

IV. LOCAL CONTROL PANEL OF UDC

The control cabinets are located in the cyclotron vault, power supply area and experimental halls, and contain control units and drive units. A control unit contains UDCs, local control panels, relay cards, analog-to-digital converter cards, multiplexer cards and interface cards for driving stepping motors and AC servomotors. A drive unit contains driver modules for stepping motors.

A local control panel is prepared for the direct control of a UDC. The firmware of a UDC contains many tasks, and task7 task in the firmware starts at 100 ms intervals for the local control panel. The panel has push-butom switches with lamps, LED indicators and a liquid-crystal numeric display. The functions of these elements are determined by the contents of task7 task, and are slightly different depending on the types of control units.

The standard usage of LED indicators is the status display of interlock conditions. The status data are stored in a communication register (CRG) area of the UDC. Only the limited important data, that are useful for the maintenance purposes of the UDC and device itself, are displayed on LED indicators. In case of power supplies the contents of CRG were fixed at the construction time, and therefore the contents of the local control panels are also unchanged. External interlock conditions may change during actual usages of power supplies. However the CRG of a power supply has only one bit for the external conditions and details are left to the CRG of the interlock system. The controls of RF systems are complicated, and all the informations were not always prepared at the design stage. Additional informations became to necessary at the adjustments of RF power amplifiers and accelerating cavities, and the local control panels were modified upon these requests. Some interlock items are added to the LED indicators after a detailed examinations on the actual control operations of concerned device.

The liquid-crystal display shows preset and actual values of the control parameter (magnetic-coil current, high voltage, position of stepping motor, etc.), and contents of CRG, input and output ports of UDC. The preset and actual values are stored in CRG as binary forms and units convenient for the device control. In case of the power supply the maximum of preset and actual values in UDC corresponds to the upper-limit current or voltage. In case of the stepping motor preset and actual values in CRG show the numbers of stepping pulses. These preset and actual values in CRG are converted to values in physical units (A, kV or mm) and display at liquid-crystal display. The firmware of UDC allows quadratic transformation for these conversions. However now only linear transformation is adopted. The same conversion coefficients are used at the main computer and the central operator console.

The local control panels are useful for the maintenance of UDCs and related modules. However the UDCs of vacuum and cooling systems have no local control panel. Local control cabinets of vacuum and cooling systems have graphic status display panels in addition to UDCs, and most informations stored in UDCs are available from indicators of these graphic display panels and control switches. If one needs the contents of input and output ports of UDCs, portable local control panels may become necessary in future.

V. INTERLOCK SYSTEM

The control unit for interlock system contains a UDC, relay cards and a local control panel. The interlock conditions are inputted to input ports of UDC and are also used in hardware interlock system through relay boards. The results of software interlocks obtained from softwares are outputted to output ports of UDC from SCU main computer and GCU subcomputers, and are used in hardware interlock system through relay cards. The contents of input and output ports of UDC are displayed on LED indicators of the local control panel through CRG data of UDC. Whenever new devices are added to the ring cyclotron and associated beam lines, new interlock items are added to the control units of interlock system. Input and output ports and relay cards of the interlock system can function as common relay input-output devices, and are used as general status displays such as operation states of AVF cyclotron and device states that belong to groups of other subcomputers.

The interlock system also communicates with the radiation protection system and the building control systems that open and shut doors and rotary shutters on beam lines. Restricting the control objects to the power supplies and motors the hardwired interlock system is rather simple. The standard control system was designed for these purposes and it is easy to include their interlock conditions as software. However, the control system of the radiation protection system was designed by different manufacture and different principles, and many patches were executed on hardwired parts after finding undesirable functions. Consequently the hardwired interlock parts as the interface become complicated ones.

VI. POWER SUPPLY OF MAGNET COIL

A control unit of the power supply of magnet coils contains a UDC, a 12-bit analog-to-digital converter and a relay card as the inputs of external interlock signals. The setting values of magnet currents have accuracy of 16 bits. Compared with this setting accuracy the measuring accuracy of 12 bits is insufficient for magnet control. The standard control units of power supplies were originally designed as 12-bit current controls by the manufacturer, and we had no room for choice at design stage. During particle acceleration the beam profile of the extracted beam varies due to the changes of acceleration conditions, and this instability influences to the quality of the measured data of nuclear reactions. To watch long term drift of magnetic field of the cyclotron magnets more accurate measurements of the trim-coil currents become necessary. In addition to this standard control system a current logging system by current recorder is in progress.

In case of 400-MeV proton acceleration the vertical betatron frequency approaches to one and the beam current reduces at larger radius. To keep the beam on the median plane and avoid vertical diversion it is necessary to generate a symmetrical vertical magnetic field disribution. The auxiliary coils of the cyclotron magnets are used for the corrections of magnetic field distribution, and one can give different current to each auxiliary coil. By adding a small power supply to an auxiliary coil, the vertical magnetic field distribution can be modified. The computer interface of power supplies adopted for this purpose was GP-IB or RS-232C interface. Both GP-IB and RS-232C interfaces are already adopted as the subboards of UDC modules for NMR field measurements and vacuum gauges, and the contents of their firmwares may be applied to the control of this power supply with some modifications.

VII. MOTOR CONTROL

The stepping motors are used for the open controls of the positions of electrostatic channels, frequency tuning devices of RF power amplifiers and cavities, variable width slits, beam probes and beam profile monitors.

The stepping motor has no present position value, and the pulse value corresponding to the present position is stored as the CRG data in RAM memories of UDC and the GCU subcomputer. Because the RAM memories are volatile, the position data must be stored in nonvolatile memory at power-off time of UDC and the GCU subcomputers. A command that stores these RAM data to a disk file of the SCU main computer is supported.

Some position controls of RF cavities use AC servomotors with a closed loop control. The closed loop control method was chosen for devices that need large torque to drive. It was not known at the design stage whether the closed loop control is adequate or not for particular devices. If it turns out that a device drived by AC servomotor has very small position tolerance and the servomechanism cannot reach to final stable state, one must change the AC servomotor to a stepping motor with large torque. One AC servomotor of the RF system was changed to a stepping motor for this reason.

VIII. BEAM DIAGNOSTIC DEVICE

For device controls and displays two twenty-inch CRT displays with touch screens of the central operator console are used. The task for the controls of the beam diagnostic devices has many functions. Some function requires prompt response, but another function does not require severe response. Therefore it is necessary to share more CPU time for the functions that require severe time response and use two displays effectively. After this improvement the simultaneous controls of beam diagnostic devices become easier.

At earlier stage of beam accelerations there was only one three-wire beam profile monitor near the extraction radius of the ring cyclotron, and manual adjustment of beam extraction process was rather difficult. Therefore two three-wire beam profile monitors were added at the beam extraction radius and different angles. Simultaneous or successive measurements by these profile monitors can determine the orbits near the extraction radius.

Main probe can measure radial beam profile from injection radius to extraction radius. The main probe has two-speed mechanism because its driving distance is large. When the beam current is measured as a function of radius, slow speed is selected. When the main probe moves to retracted position or to the starting position of measurement, fast speed is selected. The UDC controls the probe position directly for slow drive. For rapid drive the UDC sets only the final position to a driver interface, and the driver interface controls the probe position by a hardware logic. Moreover the main probe has two measuring modes, automatic and manual modes. For automatic mode the probe measures the beam current from inner preset radius to outer preset radius in sequential order. For manual mode an operator moves the probe to adequate radius and measures the beam current. Therefore there exists several combinations of operations from the central operator console. Sometimes the main probe became uncontrollable during the probe operation at early acceleration period. Thereafter some operation sequences were inhibited by the software of the SCU main computer and the operations of interface driver module was reexamined. Now the uncontrollable phenomenon of the main probe seldom occurs.

IX. CONCLUSION

The control system has improved remarkedly based on the experience of actual cyclotron operations. Some beam diagnostic devices has been added and undesirable parts have been replaced or updated. Basic facilities of the control system become to operate almost satisfactorily. Several efforts are now focused on the stable supply of good quality beams from the injector AVF cyclotron to the target position in the experimental halls.

X. REFERENCE

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