CONSTRUCTION OF COMPUTER CONTROL SYSFEM FOR RCNP RING CYCLOTRON II SOFTWARE

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Abstract

A software for a distributed computer control system of the RCNP ring cyclotron has been developed. Basic functions of the control softwares have been tested, and the control system is now in use for the operation of the RCNP ring cyclotron and beam lines.

Introduction

The computer control system for the RCNP ring cyclotron consists of a main computer that performs man-machine interface and file management, four subcomputers that control subsystems such as magnets, RF systems, beam diagnostic devices, beam lines, vacuum systems and cooling systems and and universal device controllers (UDC's) that control each device such as power supply and driving motor system.

The basic design of the control system was perfomed in 1987.[1] A software for the control system was developed in 1988 and 1989.[2] By simulating the operations of UDC's in the software of subcomputers, basic functions including man-machine interface were tested in the spring of 1990. The ring cyclotron and beam line devices were installed in new ring cyclotron building, and each device has been controlled by computers since 1990. For the device controls the computer console terminals of four subcomputers (group control units GCU using a microVAX II and three diskless rtVAX1000's) and an operator console connected to a main computer (a system control unit SCU using microVAX 3500) have been used.

Sequential Startup and Shutdown of Devices

Operations of the ring cyclotron and beam lines consist of parameter setting to devices according to a beam condition, device startups, parameter adjustments, shutdowns and fault status handlings. For realizing an automatic sequential operation, it is convenient to group many devices.

Considering an operation unit of the ring cyclotron and beam lines, control facilities are are divided into a few groups. Individual group consists of a few blocks, and each device belongs to the block.

Startup and shutdown procedures of the system can be performed by the following three methods: 1) operations in unit of group, 2) operations in unit of block and 3) operations in unit of device. In addition to these three modes an original control software developed for a common use to accelerator controls has an automatic startup and shutdown operation of the whole system by an input from the operator console. From the operational experience of existing AVF cyclotron (an injector to the ring cyclotron), the operation function in unit of the total system was deleted.

The interlocks for the individual power supplies are performed by using hardwired interlocks. Software interlocks by using fault handling procedures are considered to intend an backup function to the hardwired interlocks. However these software interlock functions have not yet tested for actual power supply operations.

The RING-GCU subsystem (microVAX II) covers the controls of injection beam line, cyclotron magnets and injection-extraction system. Devices connected to the RING-GCU subsystem belong to INJBT group or RING group. The INJBT group consists of INJBT1 block and INJBT2 block. Power supplies in the upperstream part of the injector beam line belong to the INJBT1 block, and power supplies in the downstream part of the injector beam line belong to the INJBT2 block. The RING group consists of MAINC block (power supply of main coil), AUXC block (power supplies of auxiliary coils), TRIMC block (power supplies of trim coils), MICMEC block (power supplies of injection and extraction magnetic channels), EIC block (injection electrostatic channels) and EEC block (extraction electrostatic channels). During the initial coil current setting a cycling function of the coil current has been introduced as a firmware of the UDC's. In the case of the RING group startup, at first the startup sequence (ON sequence) of the MAINC block runs. When the cycling state of the main coil becomes the third state of the cycling run, the ON sequences of remaining AUXC and other blocks begin to run. Then the field distributions of the sector magnets of the ring cyclotron become to the desired distributions. A fault state processing procedure for discharges in the electrostatic channels is included in the UDC firmwares.

The RF-GCU subsystem (rtVAX1000) covers the controls of RF system, vacuum system and cooling system. Devices connected to the RF-GCU subsystem belong to RF group or VACCOL group. The RF group consists of low level block, frequency tuning block, fine tuning block, high voltage blocks and RF-ON blocks. The ON sequence of the RF group starts the ON sequences of these blocks sequentially. At present a power-on procedure of an RF system is tested continuously by using an operation mode in unit of single device. Therefore the operations of ON sequences of the RF group and individual blocks in the RF group are not yet tested. The VACCOL group covers the devices of vacuum system and the cooling system in the ring cyclotron, the injection beam line and the beam lines.

The BT-GCU subsystem (rtVAX1000) covers the control of magnets in the beam lines that belong to BT-M block (power supplies of magnets in the main courses of beam lines) and SW block (power supplies of switching magnets). For a future construction of the subcourses allowing an simultaneous beam supply to two beam course by using an AC switching magnet, BT-S block (power supplies of magnets in the subcourses of the beam lines) is reserved. At present a beam course for the cyclotron tuning and four beam courses to three experimental halls have been constructed. Magnets in the beam course to experimental halls share their power supplies. By using a power-line connection system one power supply can change its connection to seven or eight magnets in different beam course. After setting parameter values are loaded from a file and selecting corresponding new beam course, one can change each coil load from a old beam course to new beam course.

The DIAG-GCU subsystem (rtVAX1000) covers the controls of beam diagnostic devices. Devices connected to the DIAG-GCU subsystem have no sequential control in unit of group or block. However they belong to DIAG1 block or DIAG2 block for convenience because the number of UDC's connected to this subsystem is too large.

Software Interlocks

The interlock system for power supplies, a beam handling and an interface to the radiation protection and the injector cyclotron has been constructed by using hardwiring and conservative relays. Software interlocks using sequence programs, written by a basiclike interpreter-type language, are also supplementarily executed on GCU subcomputers. Processes of SCU main computer also contain software interlock facility.

Devices are controlled by the universal device controllers (UDC), and hardwired interlock signals are also connected to UDC's in an interlock unit. Many interlock units are distributed to control cabinet racks: two units for cyclotron magnet coils, eight units for RF cavities and amplifiers, two units for injection and extraction devices, six units for beam lines, and also for beam diagnostic devices and radiation protection system. Each UDC for interlock handles 48 digital inputted signals and 16 digital output signals. Interlock signals such as flow switches of magnet coils are inputted to digital input port of the UDC in addition to the hardwired interlock circuits. These signal data are sent to GCU subcomputers and the SCU main computer. The digital output port of the UDC connects the hardware interlocks and the software interlocks.

The software interlock conditions are created by softwares in GCU computers and a SCU main computer. Each digital output signal of the UDC has an operation name correspondig to its function, and the software interlock conditions are outputted to UDC's by referring operation names. The digital outputs are taken into hardware interlock relay circuits. Excess beam current on slits at beam lines and in the ring cyclotron will stop beam before acceleration by using this software interlock facility. After this interlock system sends an information on a selected beam line to the radiation protection system, the control system receives additional interlock data concerning a safety condition on transporting beam to the specific beam course in experimental hall. The degree of vacuum data can be also used as software interlock conditions. Compared with the hardware interlocks the flexibility of the software interlock function is very useful for the dynamic change of interlock threshold values to actual parameters. However detailed information for this software interlock system is not yet prepared now, and an arrangement relating to their database is left for future software modifications.

Another type of the software interlocks is a direct output of the interlock conditions to the UDC of power supplies and motor drives. Fault sequence programs in GCU subcomputers can control the status of power supplies and other devices by using their operation names.

Adjustment of Device Parameters and Display of Device Status

Device states can be displayed on two twnty-inch CRT displays with touch screens of the operator console. As previously described in ref.2 screens for device status, not ready device list, fault device list and dynamic parameter value are prepared. These values are also displayed on the computer console terminals of subcomputers (GCU's), and are useful to check the control funcions for not only maintenance aids but also daily stationary operations.

In the early stage of the construction operational tests of the control systems of devices were performed at the local control panels of the control units in the cabinet racks installed in and near the cyclotron vault and experimental halls. After completing installations and checks of the control system for devices, their control functions were confirmed by GCU subcomputers and finally by the SCU main computer.

All the control informations of each device is displayed on a memory of the UDC called communication register (CRG). The GCU subcomputers usually have updated copies of the CRG data of UDC's. According to the requests from the tasks of the SCU and the operator console, the main computer gets necessary CRG data by the operation names from the corresponding GCU subcomputer. After defining the operation names on the main computer, the device control functions can be checked from the computer console terminal of the GCU by using not bit images of the CRG but more familiar

names based on the operation name. In this process the validity of the operation names can be also checked. Next the control functions are checked from the central operator console that is connected to the main computer. Twentynine processes (tasks) run on the SCU with issuing mails between processes, and therefore total software system is rather complicated. Sometimes it is necessary to run a particular process with a debugging mode for checking purpose. After finishing these procedures, the control software itself became open to general operators of the ring cyclotron system in the spring of 1991.

During the checking procedures of the control functions both the displays of GCU and the operator console are used simultaneously. A device control is initiated from the operation screen of the operator console by selecting particular cell. Then the following control result is displayed on the display of GCU, and the control function can be confirmed. They are perfomed by comparing device states, presetting values and measured actual values on both GCU and SCU (operator console),

Trend Display

Variations of coil currents, degrees of vacuum and temperatures of cooling water can be displayed graphically on the trend display screen of twnty-inch CRT display. Three screens for the trend displays are prepared, and each display shows eight parameters.

On the first stage operation of the ring cyclotron this trend display facility was very useful. For the startup procedure of the power supplies of the ring cyclotron magnet coils, one can use the ON sequence operation of the RING group and the trend display of magnet coils. A cycling pattern of the main coil current together with auxiliary and trim coil currents can be recorded on the same trend display screen. On the operations of electrostatic channels and RF systems one can use the trend display to show the relation between the degree of vacuum and high voltages and leakage currents of the power supplies for a diagnostic purpose.

Communication with Control System for Experimental Instruments

By using a power-line connection system one power supply can change its connection to magnet coils in beam lines and experimental instruments. Many devices in the beam lines are controlled by the SCU main computer. However it is also necessary to control some devices that are connected to SCU from experimental side for some specific processes such as dispersion matching.

The communication function between the SCU main computer and a control computer for experimental instruments is realized by a process named PCP (PC communication process) in SCU. This process opens a link to other computers with a name of PCP-PORT, and it is necessary that the control computer for experimental instruments establishes a logical link to this port.

The PCP process handles functions such as connection-disconnection of the communication, conversion from operation names to operation name numbers for the speedup of data access, device parameter transmission and adjustment, device on and off operations, device status monitoring, and operation and data transmission of beam profile monitors.

A VAX computer in the new counting room performs the man-machine interface of the control system for experimental instruments, and is connected with intelligent VME crates for the control of experimental instruments and the SCU main computer. Some functions of the PCP process have been tested, but the test of position control and data acqusition of beam current for the beam profile monitors is not yet finished.

Local Consoles of Subcomputers

Each GCU subcomputer has one console terminal, and at system startup and maintenance times one can control UDC's and associated devices by using this display terminal. The GCU subcomputer has two operation modes, local and remote modes. For the switching between two modes an operation mode screen is used. The local mode permits both displays and controls, but the remote mode permits only

the status displays. On remote mode the SCU main computer has all the control authorities, and all the device controls are executed by the commands from the SCU main computer. The mode setting can be done in units of groups. In case of some troubles of the SCU main computer or network between SCU and GCU computers the GCU mode is switched to local mode automatically.

The UDC status display shows a communication status between GCU subcomputers and UDC's. Possible UDC states are unregistered, remote mode, local mode, offline, error and warning states. When a communication line between GCU and UDC is normal and UDC is controlled by GCU, the UDC status is remote mode. When a communication line is normal and SCU receives UDC informations but UDC control is performed by itself, the UDC status is local mode. When the power supply of UDC is shutdown and the communication line is disconnected by software, the UDC status is offline. When the communication line is connected but its contents are abnormal owing to a transmission data error, the UDC status is error. If the power supply of UDC becomes to shutdown while a communication continues, the UDC becomes to error states. The communication lines between a GCU and UDC's are light fiber cables and are connected in tree structure by using a signal distributer called a message tree brancher (MTB). If an MTB has a vacant bare port to that no fiber cable is connected, the communication line has a possibility to become error state due to a disturbance of external light noise. To recover a UDC from this error state, one must disconnects the communication line and again connects the line.

The start/stop screen is used to start and stop devices and also display device status in unit of groups, blocks and devices. If one selects a subscreen of device operations, the informations on dynamic parameters, device dependent parameters, UDC status, commands and status are displayed, and it is possible to issue commands for device operation, adjust parameter values and change the communication status with UDC. This screen is very useful and convenient for the initial stage of the ring cyclotron operation. When it becomes necessary to control a device parameter not registered on the operation screen of the central operator console that is controlled by the SCU main computer, it is possible to control that parameter by using this device operation screen of the GCU subcomputer as far as corresponding operation name is registered. If the operation name is not registered in SCU and GCU computers, one must directly write the data to the CRG area of the UDC by the aid of a utility program. Dynamic parameter values such as coil current and device position are displayed both in physical units and in digital pulse values, while on the display screen of the central operator console only the values in physical units are displayed. Therefore the device operation screen is useful for maintenance and debugging aids.

The fault trend screen displays the informations such as device status, detailed information and parameter value of device on fault occurrence. The alarm information screen displays alarm informations by overwriting upto 256 items in time sequential series.

Fig. 1   Central operator console.

Initial Operations of the Ring Cyclotron

Software of the control system has been constructed assuming the usage at final stage of the particle acceleration. For example, the interlock checks is to be executed throughout from beam injection to beam dumps in the experimental halls. However an initial beam test of the ring cyclotron was restricted to the beam injection part, and it is necessary to modify both hardware and software interlock sequences depending on particular test purpose.

The group and block start/stop facilities have been used partly. The start and stop sequences of injection beam line group and cyclotron magnet group have been executed several times upto now, but the startup procedure of devices for RF system is executed manually one by one. As the data on frequency and position relations of cavities and relating devices have not been included in the software properly, an automatic frequency tuning procedure for RF system is not completed.

During the initial startup procedures the use of a trend display is very useful for the checks of operation itself and firmware contents of the UDC's such as cycling procesure at startup time of the power supplies of magnet coils. For the startup procedure of high voltages of RF cavities and electrostatic channels rather complicated time sequences are considered, and their operations were confirmed together with the variation of degree of vacuum in the cyclotron chamber and also leakage currents.

Interlock system concerning with beam stopper and radiation protection system was tested for hardware wiring only using actual ring cyclotron operation, and the tests for software interlocks is left for future beam acceleration.

Trivial troubles on the operations at the central operator console were temporarily fixed by using the console terminals of the GCU subcomputers, and the software of the SCU main computer will be updated by including this operational experience.

During a beam injection process of the ring cyclotron many beam diagnostic devices such as slits, beam profile monitors and beam viewers have been applied, and many checks on device position and beam current measurement including noise current observation were done. For slight beam current the lack of beam viewers in injection part of the cyclotron made the beam tranport procedure to be difficult.

Continuous investigations on reliability and reproducibility of the control system are necessary for the present particle accerelation period.

Conclusion

The accerelated proton beam from the injector AVF cyclotron has been injected to the ring cyclotron and the computer control system is used for the beam accerelation of the ring cyclotron. The software of this control system performs its basic facilities almost satisfactory under actual cyclotron operation.

References

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