CONSTRUCTION OF COMPUTER CONTROL SYSTEM FOR RCNP RING CYCLOTRON I HARDWARE

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Abstract

A distributed computer control system for the RCNP ring cyclotron has been constructed. For the control of each device the universal device controllers are used. Their basic functions are described in detail.

Introduction

The control system consists of a computer network with a central computer (a system control unit SCU using micro VAX 3500), four computers (group control units GCU using a microVAX II and three diskless RTVAX1000's) and many control panels.[1,2] The RING-GCU subsystem (microVAX II) covers the controls of injection beam line, cyclotron magnets and injection-extraction system. The RF-GCU subsystem (RTVAX1000) covers the controls of RF system, vacuum system and cooling system. The BT-GCU subsystem (RT-VAX1000) covers the control of magnets of the beam lines. The DIAG-GCU subsystem (RTVAX1000) covers the control of beam diagnostic devices.

The control cabinet racks locate in the cyclotron vault, experimental halls and power supply area, and contain universal device controllers (UDC's) which control component devices, associated local control panels, the drivers of the stepping motors and AC servomotors, input signal multiplexers, analog-digital converters and interlock relays. The firmwares of UDC's have been determined, manufactured and tested according to many specifications on standard functions and additional functions especially necessary for the control of the new ring cyclotron. A control unit contains upto three UDC's, digital and analog input-output ports, a local control panel and special function boards such as an analog-digital converter and a multiplexer for the input of analog signals. The control units as the components of the control system were tested using the control devices such as power supplies or stepping motors at the factory, and were installed in the new ring cyclotron building in autumn of 1990.

Power Supplies of Magnet Coils

The UDC's and associated local control panels are installed within power supply cabinets of the cyclotron coils, i.e., main coils, auxiliary coils, trim coils and magnetic-channel coils. The communication data between GCU computer and UDC are stored in the memories of UDC named a communication register (CRG). The CRG formats of all magnet coils of the ring cyclotron and beam lines are same. However there are three types of firmwares in UDC's depending on the specifications of power supplies. They are classified to main magnet coils, other magnet coils of cyclotron and the magnet coils of the beam lines.

Ring Cyclotron Main Coil

The power supply of the ring cyclotron main coil uses a high precision digital-analog converter for the coil current setting, and its CRG has unique status bit corresponding to its GP-IB interface.

The firmware of the power supply control for the main magnet coil consists of six tasks. Task1 starts at 200 ms intervals to initialize the GP-IB interface, output a preset value, and read the current value. Task2 is a communication task, and uses the CRG as the communication area. Task3 starts at 10 ms intervals to calculate the output current value depending its cycling mode which set the ratio of the output value to the final preset value. Task4 starts at 10 ms intervals for the operation of the sequence control depending on the present status and setting commands. They are the startup and shutdown sequences, the polarity change of the output current, and the interlock and status monitorings and corresponding status transition operations. Task7 starts at 100 ms intervals for the local panel controls. Task8 starts at 100 ms intervals for the GP-IB input-output processings.

Trim Coils, Auxiliary Coils, Magnetic Channel Coils, and Magnet Coils of Injection-Extraction System

The power supply cabinets of magnet coils of the cyclotron and injection-extraction magnets contain the current supplies to more than one coils in general. Therefore, the startup and shutdown operations are common to all coils in the same cabinet. One master UDC has a responsibility for the operations common to all UDC's in the same cabinet. The firmware consists of five tasks. Task1 starts at 10 ms intervals to read the actual coil current values with a stability check and output the data to CRG. Task2 is a communication task. Task3 starts at 10 ms intervals to calculate and set the output current values to the digital-analog converter. There are two output setting modes, the normal mode and the cycling mode. In the case of the normal mode the output value is varied step by step from the present value to the final preset value by adding the constant small value in the constant small time intervals to the present value. In the cycling mode the output setting in each cycling stage is realized by the same method as the normal mode, and after passing through a few cycling stages the final preset value is outputted to the digital-analog converter. Task4 starts at 10 ms intervals for the sequence control operations such as the startup and shutdown sequences, the polarity change of the output current, and the checkings of the interlock status and the operation status. Task7 starts at 100 ms intervals for the local panel controls.

Power Supplies of the Electrostatic Channels

The hardwares of the control parts for the power supplies of the electrostatic channels are same as those for the power supplies of the cyclotron magnet coils except the main coil. The UDC controls against a discharge at the electrodes of the electrostatic channels and the reading of both output voltage and output current.

The function to output a preset value is rather complicated. Before setting a preset value VS the initial preset value V0 and the intermediate judgment voltage VI must be defined. If VS value is smaller than V0 value, VS value is directly outputted to a digital-to- analog converter. Otherwise V0 value is outputted at first. The output value is increased by dV1 at T0 time intervals before reaching VI value. After passing through VI value, the output value is increased by dV2 at T0 time intervals. Finally the output value becomes the preset value VS, and a stability check function starts. If a discharge phenomenum is detected during the voltage setting process or after the voltage setting, the output voltage value to digital-analog converter is compared with a measured actual voltage value. If its difference is greater than a stability checking value dP, the device status varies from an operational state to a fault state.

Power Supplies of the RF Systems

Power supplies of intermediate stage and final stage amplifiers were constructed since 1987 in the early stage of the construction of the ring cyclotron, and the designs to control the power supplies by using UDC's were not in time. Therefore the control units including UDC's were connected externally to the power supplies already completed. On the contrary other power supplies were designed by assuming the controls using UDC's together with associated local control panels, and control units containing UDC's and local control panel were included inside the power supply cabinets. The power supplies of the RF system amplifiers can be operated locally without using UDC, but other power supplies such as magnet coils of the ring cyclotron and the beam lines cannot be operated without UDC even in a local control mode.

The firmware of the power supply controls for the amplifiers of RF system consists of five tasks. They are input of actual values from an analog-digital converter, a communication task, output of preset value to a digital-analog converter, sequence controls including startup and shutdown of the power supply and checking functions of interlock and status signals, and local input-output controls.

The control parts of an RF low-level system consist of a voltage adjustment, a phase adjustment and an automatic tuning functions. There are two operation modes, pulse mode and normal constant wave mode. The pulse mode is used at startup time of the RF system. The voltage control of RF system is similar to that of electrostatic channel. If the final preset value VS is smaller than a predetermined initial value V0, the VS value is directly outputted to a digital-analog converter. Otherwise V0 value is outputted at first. The output value is then increased by dV at T0 time intervals. Finally the output value reaches to the preset value VS, and a stability check function starts. If a discharge phenomenum is detected during the voltage increase, the voltage setting starts from the value dV1 smaller than that just before the discharge. The operation mode is set to pulse mode on discharge. When the operation mode is not returned to constant wave mode and still remains in pulse mode at T-DELAY time after the discharge, the next setting value is decreased ten percents from the previous output value, and the voltage increase starts from that value.

As shown in ref.3, harmonic numbers of accelerations at the ring cyclotron are 6, 10, 12 and 18, and ratios of the RF frequency of the ring cyclotron to the AVF cyclotron are 3 and 5. These relations determine the RF phase differences between three accelerating cavities and a flat-topping cavity. The UDC for the phase adjustment of RF low level system reads the detected phase values and outputs new setting value for RF phase. The UDC for an automatic tuning of RF low level system reads an injected power from the final stage amplifier, a reflected power from a cavity, an amplitude and a phase of the input impedance to cavity.

Controls of Stepping Motors and AC Servomotors

The stepping motors are generally adopted for the open-loop position controls of electrostatic channels, frequency tuning devices of RF power amplifiers and cavities, variable width slits and beam probes. On the controls of the shorting plates of upper and lower tuning devices in cavities, two stepping motors can be driven simultaneously.

At startup time the UDC for the driving of stepping motor has no pulse value corresponding to the present position. Then on startup a GCU subcomputer downloads the pulse count of the position at previous shutdown time, otherwise new pulse count must be set at limit switch position for a calibration. One UDC can control upto four stepping motors. When the UDC receives a drive command from the GCU subcomputer or a local control panel, the UDC controls the positions of a device by outputting control pulses to the driver module of a stepping motor. The UDC controls hold and brake functions and also interlock conditions if necessary.

Some position controls of RF cavities use AC servomotors with a closed loop control. One UDC can control upto four AC servomotors. After selecting motor number, the UDC reads the present position from a potentiometer through analog-digital converter, determines driving direction by comparing the present value with a preset value, and outputs driving signals until reaching to final preset position by checking interlocks relating the driving direction.

In a normal operation mode the positions of many stepping-motor driven devides such as electrostatic channels, shorting panels of RF systems and variable width slits are not calibrated so often by using a function to reset the pulse numbers at a retract position. Therefore the positions of motor driven devices must be checked by reading the position values of associated potentiometers. The UDC for the potentiometers reads 32-channel data effectively and periodically from potentiometers through four 8-channel multiplexers, and writes the digitally converted data to communication register (CRG) area.

Interlock System

Device status signals used for external interlocks to other devices are collected in an interlock control unit through a signal distributor box with terminal boards and status display lights. The control unit contains a UDC and relays to output the signals for an interlock circuit. The UDC also has functions to initialize the UDC status, read 48 interlock signals and set the data to CRG, output 31 signal data set in CRG by GCU subcomputer to output relays, display and control at a local control panel, and communicate with GCU subcomputer. Eleven UDC's are prepared for the interlock system of ring cyclotron. There are two for main magnet, four for RF amplifiers, four for RF cavities, six for beam lines, two for injection and extraction devices, and also for beam diagnostic devices, experimental apparatus and building including radiation protection.

Beam Diagnostic Devices

According to a standardization for the usage of the UDC comparatively resticted functions are assigned to each UDC. For example, they are stepping-motor drive, air-cylinder drive and multiplexer for input signals. However some beam diagnostic devices have a coupled control of these functions such as a beam measurement as a function of position, and use a special UDC for these purposes.

A main probe has a beam stop with three-wire profile monitor facility. Main probe is used with manual mode or automatic measuring mode. A UDC checks the status of flow switch and position limit switch, and set ready state according to the flow switch status. The UDC has a function of offset correction to measured beam current. In automatic measuring mode beam currents are measured as functions of position. Start and stop positions are determined before the measurement, and fast movement is introduced for large distance driving.

Fast rotary scanners by using supersound motors near injection line and near extraction radius are controlled by single UDC. This UDC has a function of initial parameter settings. Gain data set in CRG area are outputted at 200 ms intervals. Retracted position signals of scanners are checked at 10 ms intervals. Motor control task starts at 200 ms intervals. A retract command drives scanner to retracted position and stop motor after 10 ms. A start command starts motor rotation to measuring position. The UDC also controls a local control panel, and communicates with DIAG-GCU subcomputer.

Phase probe systems installed in injector line, extraction line and vacuum chamber of the ring cyclotron use three UDC's as a whole, and the UDC's control a frequency synthesizer, a pulse generating circuit and multiplexers for input signals. Multiplexed signals from phase probe and beam currents of fast rotary scanners are stored and displayed on digital oscilloscopes at the operator console, and the data can be stored to SCU main computer through GP-IB interface.

A UDC is assigned for vertical and radial position controls of the energy-phase monitors installed near injection and extraction radii. An air cylinder driving controls a thin wire probe from retracted position to the median plane of the ring cyclotron magnets. A stepping motor drive sets the probe to measuring positions on the median plane with manual or automatic position changing mode. Measured data of elastically scattered particles by a fast scintillation radiation detector are sent to SCU main computer through RS-232C interface to get the relation between beam phase and beam radius.

An emittance monitor installed in injection line uses a UDC for the system drive and beam measurement. An AC servomotor is used to rotate the system for horizontal or vertical measurement. Slits and detectors are driven simultaneously by open loop control of stepping motors. Beam currents at 64 detectors are sent to UDC through eight twelve-bit analog-digital converters with eight-channel multiplexers. The UDC has a function to initialize status inputs and gain settings. Flow switch and limit switch states are read at 10 ms intervals. For offset-read command actual current values are stored as offset data to beam currents. For beam-current input command UDC executes channel setting of multiplexer, analog- digital converter start, data input and offset correction sequentially. Automatic measuring function executes position setting and beam current measurement for both horizontal and vertical directions based on a command from SCU main computer. Beam data stored in buffers are sent to SCU main computer, and beam emittance can be obtained.

Beam Viewers and TV Displays

The position of a beam viewer in beam line is controlled by an air-cylinder drive. A UDC can drive upto four beam viewers. Control task starts at 50 ms intervals, and inputs limit switch position status and outputs drive signal of the viewer, power-on and power-off signals for a camera and a light. Task for the local control panel starts at 100 ms intervals.

An ITV controller switches eighty ITV cameras for eight TV monitors. Forty ITV cameras are assigned for beam viewers, and remaining forty cameras are assigned for watching inside experimental halls, cyclotron vault and other rooms. Eight video signals are forked respectively. TV monitors are installed in the operator console and also in the counting area. The ITV controller is controlled by a UDC and eight personal computers. Task3 starts at 50 ms intervals, and sends channel and other data to the ITV switching circuit. Task4 starts at 50 ms intervals, and sends camera name and time information to personal computers. Their data are inserted into the video signal. Task8 starts at 100 ms intervals, and controls the local control panel.

Vacuum and Cooling Systems

The vacuum and cooling systems of ring cyclotron and beam lines are also controlled by using UDC's. A UDC for the vacuum system of the ring cyclotron controls upto three devices from vacuum pumps and vacuum valves, and the number of UDC's used is 18. This UDC handles bit informations concerning startup and shutdown of vacuum pumps, open and close operations of vacuum valves, status displays on interlocks and degree of vacuum, execution of sequence operation together with ready and fault checks, local panel operation, and communication with RF-GCU subcomputer. From the operator console it is possible to start a sequential operation of vacuum pumps and vacuum valves, and it is not intended to operate individual pump separately. Two ionization vacuum gauges at the vacuum chamber of the ring cyclotron are connected to UDC through RS-232C interfaces and SBX boards. The UDC handles vacuum gauges at 100 ms intervals. The handling functions of UDC are filament operation data, input of degree of vacuum, degassing operation and communication with RF-GCU subcomputer.

A UDC for the cooling system of the ring cyclotron controls upto six devices from cooling pumps cooling valves, and total number of UDC's used for the control functions is three. This UDC handles bit informations concerning startup and shutdown of cooling pumps, open and close operations of cooling valves, status displays on interlocks and water levels of tanks, execution of sequence operation together with ready and fault checks, local control panel operation, and communication with RF-GCU subcomputer. On the operator console only the status display is possible on the cooling system, and it is assumed to operate cooling pumps and valves only from the local control panel. Water temperature monitoring units are connected to UDC's through six channel multiplexer with upper and lower temperature limit switches. Total number of UDC's used for temperature monitoring on the ring cyclotron system is four. The UDC executes a monitoring sequence to measure water temperature and sets high, good or low temperature status.

Control of GP-IB bus

To measure the magnetic field of magnets in the cyclotron and beam lines, an NMR measuring device with ten channel multiplexer is connected to a UDC through GP-IB interface. The UDC sets measuring range, sweep speed and other commands necessary for field measuring, selects a multiplexer channel, checks a lock status and gets a measured field value. The number of NMR devices are one for injection beam line, one for the ring cyclotron and three for beam lines. A digital voltmeter with eight channel multiplexer is connected to a UDC through GP-IB interface. The UDC sets measuring range, reads rate and other commands to digital voltmeter, selects a multiplexer channel, reads measured data and converts them to binary values. Frequency synthesizers for RF system and phase probe are also controlled by UDC's through SBX boards of GP-IB interfaces. The UDC sets frequency and output level to corresponding frequency synthesizer. Output frequency for the phase probe system is calculated from RF frequency of the injector cyclotron and other related parameters.

Conclusion

The computer control system for the RCNP ring cyclotron is distributed to the control units including universal device controllers, four subcomputers and a main computer. The hardware part of the control system has been almost completed, and the control functions are now executed by computer softwares.

Regarding RS-232C interface, only the degree of vacuum data from vacuum gauges are sent to UDC's using RS-232C interfaces. Counting data from RS-232C interface of a pulse height analyzer used at an energy-phase monitor of the ring cyclotron are directly sent to SCU main computer.

References

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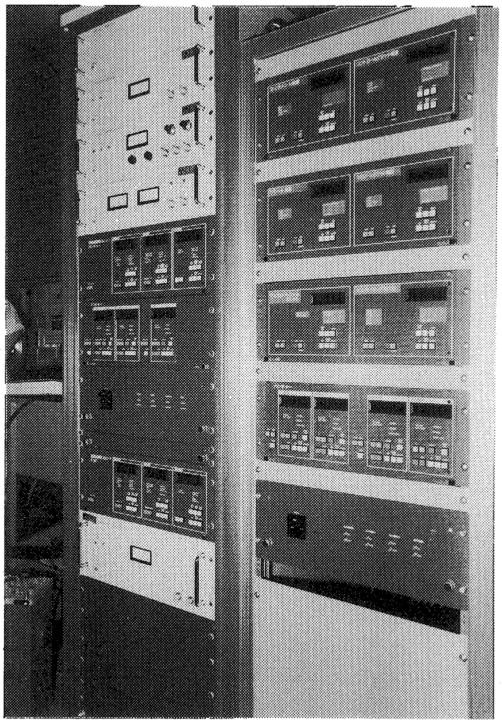

Fig. 1. Control units containing universal device controllers and local control panels are installed in control cabinet racks.