COMPUTER CONTOROL SYSTEM FOR THE SUPERCONDUCTING ELECTRON STORAGE RING NIJI-III

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GENERAL DESCRIPTION

The NIJI-III is a compact synchrotron light source for industrial application. The present system is designed with a view to attaining a high degree of accuracy in determining and controlling the ring system as a whole.[1]

The system comprises a master controller by which the operator concentrically control the total ring system, and ring controllers by which the injection module and the magnet power supply are supervised, while the independency of the both being improved by utilizing interconnection via the optical fiber communications network. The superconducting coils are super precisely controlled by applying soft starting control and high-speed arithmetic and logic processor for the resident monitorring and error correction.

HARDWARE

System configuration

This system is based on the decentralized control in which the distributed microprocessors contribute to the cost performance. Comprised with the vertically separated modules, namely the master controller acting the part of a console computer and the ring controllers covering the detailed reading and supervising of the objective items, the entire system constitutes up-and-down structure in its operating function. Likewise, the horizontal distribution is accomplished by classifying the ring controllers' tasks, ie., the injection controlling module for the ring controller 1, and the lattice forming module for the ring controller 2.

Each controller is connected by means of token ring system which provides N:M data communication via the lightwave transmission. Communication between the ring controllers and each controlling objective devices is established by the the built-in E/O and O/E conversion interface board in terms of 1:1 inter-block mutual lightwave communication.

As a result, the present system as shown in Fig.1 has following features.

1. System's open-end which allows for high degree of expandability and modifiability.
2. Decreasing the number of connecting cables between the controllers.
3. Providing greater immunity to electromagnetic interference.

Controllers

Each controller comprises a CPU, inter-controller communication interface, and a series of interfaces at the target devices, each being inter-connected by an VME bus -- one of the most popular buses. With respect to the CPUs, 16-bit micro-processors are used for the master controller and the ring controller 1, and 32-bit microprocessor and a high-speed floating-point arithmetic processor are used for the ring controller 2 for which the high-speed calculation is required.

Interface between ring controller and control objective device

The numbers of the signals of the current/voltage input, current/voltage regulating, time setting, and ON/OFF command are 16, 15, 2 and 87, respectively.

The transportation of 16-bit messages of the current/voltage regulating call which have been processed in the ring controller's CPU, ON/OFF command and such ON/OFF data as normalcy/abnormality checking has been accomplished by providing an optical fiber data linkage transmitting the serial signals to both the controllers and the telemeters. Current/Voltage metering analog signals are submitted to V/F and E/O conversion, and are trans-mitted to each controller via the optical fiber communications network. The transported signals are finally dealt with in terms of 16-bit measuring information integrating the frequency in the IC counter after O.E.C. at the controller.

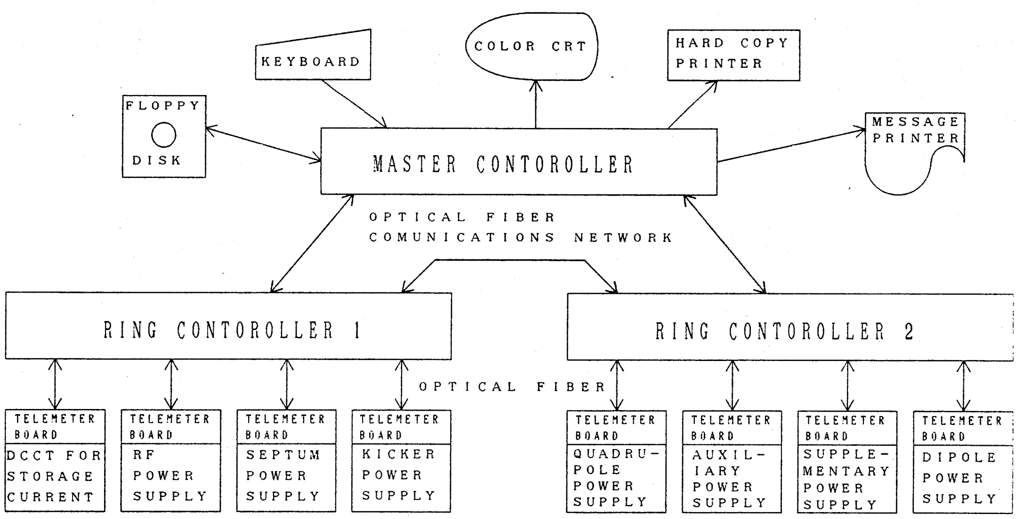

FIG.1 SYSTEM BLOCK DIAGRAM

The reasons why V/F conversion is applied instead of A/D conversion can be classified into following two respects,-.

1. It is possible to cut down in the cost of equipment as well as space performance sake in installation.
2. All of the metering signals are carried in DC.

The measured value is determined by calculating the measured frequency by FV relational expression in first order function (can be computed out of the respective frequencies corresponding to the base voltage and to zero level, which is actually conducted by the software in the ring controller), each time the measurement is taken.

Thus, the measurement with the high degree of accuracy was acheived with minimal influence of the temperature shift or aging shift of the measuring elements. The results in the super-precision faculty was applied to the lattice magnetic field control.

The operation delay of the septum and kicker power supplys is conducted by means of the telemeter board comprising the clock utilizing a crystal resonator (this determines the unit second responsing the delay shifts) and the counter by which the delay counts are to be set in accordance with the instrction from the ring controller via the optical fiber communications network. The pulse current value for the septum and kicker power supplies are measured in the procession of high-speed peak hold and the 12-bit ADC is applied in the current metering telemeter board, then is digitally dispatched to the ring controller via the optical fiber communications network.

SOFTWARE

Command system

The operational command system of the present system is classified into the "Machine Studying Operation" and the "Routine Operation", for which the following modes (two sorts) are self-contained to facilitate the operation.

1. 'Operation preparatory mode' setting the range of parameters in preparation for the measuring control.
2. 'Control Mode', controlling objective items such as power supply for coil.

The following are the explanation of functions pertaining to the system operational command.

1. Injection
   The pulsed power supply is controlled until the stored current reaches the "target of stored current" in the process of probing the greatest efficiency.
2. Acceleration and deceleration
   All of the power supply current of the lattice forming coil and the rf power source energy for the cavity are varied in proportion to the exciting current of the dipole coil until the beam energy reaches the final energy.

System configuration

Fig 2 shows the configuration of the software reference. The present system is not of the type having the standard keyboard of the conventional computer system but constitutes an exclusive apparatus which can be easily operated by an operator. Consequently, the finished structure is rather simple when compared to the initial design because the software system has been modified by omitting the superfluous systems used at the time of the development.

At the stage of the system development each controller is connected to the work-station equipped with UNIX by means of Ethernet. Each application program which has been developed in the work-station utilizing the diversifying UNIX's programming generation tools will, after stowed away in the disks, be downloaded and executed at each controller, via the Ethernet. At each controller, the real time monitor which has the network system compatible with UNIX execute the application program which has been downloaded before. It can be said that this system adopted UNIX to improve the efficiency of the system development.[2] With respect to debugging, the real time debugging function of the real time monitors were utilized.

In routine operation the real time monitors which are existent in each controller play the parts of OS to execute each application program stored in ROM.

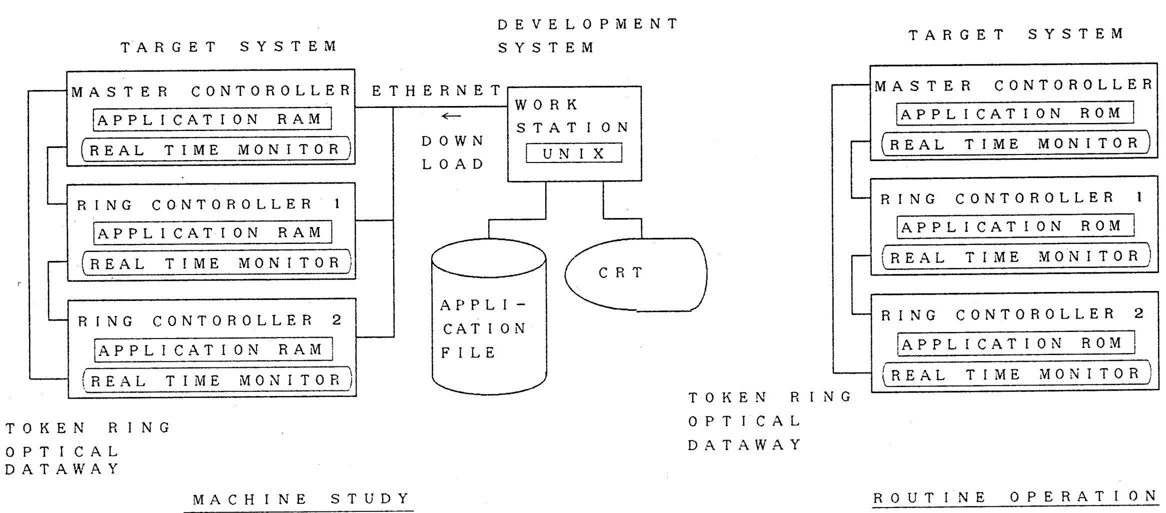

FIG.2 CONFIGRATION OF THE SOFTWARE

CONTROLLING ALGORITHM

Algorithm in the magnetic field control

This algorithm is used by the processing command which controls the current cooperating the magnet power supplies.

The ring controller CPU attempts to control the value of the current throughout the relevant power supplying assemblies for the superconducting bending coils, one for the dipole, four for the auxiliary, four for the supplementary and three power supplies for the quadrupole magnets, with a reasonable amount of patience to the predetermined ascending (descending) curve toward the final current value which is specified by the operator beforehand. During the control, the CPU is calibrating the measurement to the setting value, the differential (=error) of which shall be PI feedback in order to improve the trackability toward the predetermined curve.

Fig.3 shows algorithm for controlling main power supply current. The controlling function of the dipole coil power current is basically expressed in the Laplace transformation, ie.,

$$Ubm(s) = (\alpha/S^2)\cdot(1/(1+Ts\ S))\cdot(1+Td\ S) \qquad (1)$$

where α/S^2 is an ramp function, and the current ascending rate set by the operator at the master controller. The control is conducted in the interval of approximately 30ms.

1/(1 + Ts S) smooths the beginning and end of the above mentioned ramp function to ensure the correction by feedback control.

If the CPU setting current at each stage of the controlling interval should be directly flowed into the superconducting coil, the terraced waveform may appear to activate the quench protecting circuit because a high voltage will be generated at the rising edge of the terrace. Therefore each power supply uses 1st dimentional delay circuit at the input only to damage the control function.

To compensate this drawback, the 1st dimentional advancing element (1 + Td S) has been added. The circumstance is the same to the auxiliary, supplementary, and quadrupole magnet currents controlling. As an added faculty, the proportion to the main power supply and its variations have been given to meet the 1st dimentional interpolation.

Algorithm for injection

The injection efficiency is made maximum by using 'Automatic Control Command' on "Injection" and controlling puled power source.

By metering the pulse current in terms of peak hold, pulsating power charging voltage is controlled in minor degree to let the preset pulse current flow. Furthermore the septum current is controled so as to improve the injection efficiency up to its maximum, in a certain interval of measuring the stored current.

SUMMARY

Presently the computer control system is in operation for the machine study of the NIJI-III ring . The function and the algorithm of this system are now experiencing the practical test.

For the fully automated control system, it is expected to develop an electron beam transporting system, the controlling system of the vacuum pump sequence supervisory device, as well as the beam position correcting equipment to fulfill the throughout automatic system.

ACKNOWLEDGHMENTS

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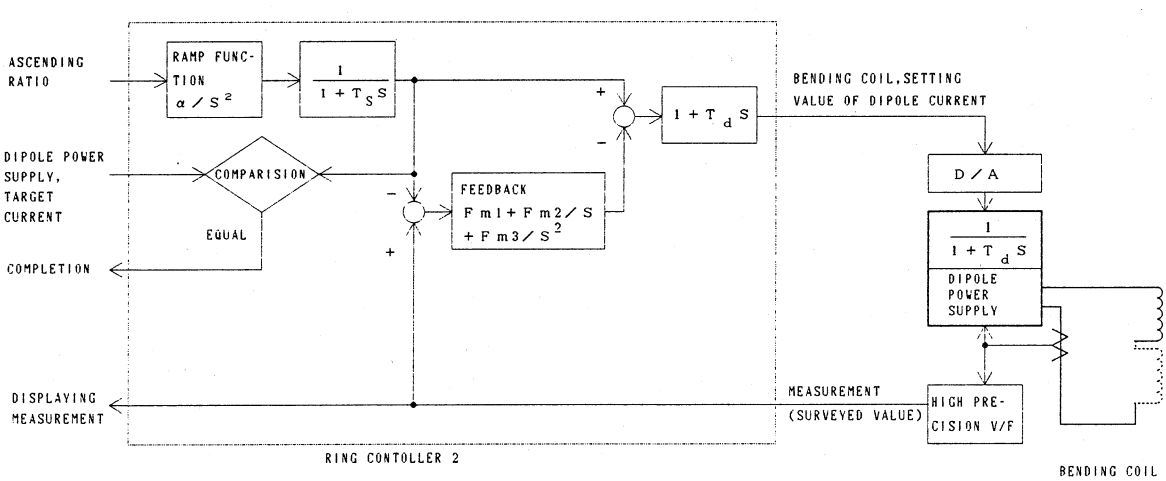

FIG.3 BENDING MAGNET POWER SUPPLY CURRENT CONTROLLING ALGORITHM