

POWER SUPPLY CONTROL SYSTEM FOR TARN-II MAIN RING MAGNET SYSTEM

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Summary

The control system for the TARN-II magnet power supply system have been developed. The control system consists of the MULTIBUS based distributed micro-computer system with operating system CP/M-86™. The main-computer and four sub-computer are provided for the pattern generations and self corrections. The data transfer is carried out with the DMA controller. The control program is developed by the main-computer using the macro assembler and executed by the sub-computer with the own made interpreter. Test of the power supply is being carried out with this system.

Introduction

The four set magnet power supplies have been constructed for the main ring magnet system ¹⁾ of synchrotron and cooler ring -TARN2- ²⁾. The one is for a dipole magnets and the other is for three groups of the quadrupole magnets. The specifications of power supplies are listed in Table.1. The operating pattern of the magnet current is a trapezoid wave form with a repetition rate of 0.1 Hz. The current and voltage patterns of bending magnet are shown in Fig.1.

The bending magnet power supply comprises 12-phase thyristor valves with the ACR and AVR loops. The reactor transformer type active filter is also provided for suppress the ripple component in the magnet current. The block diagram of bending magnet power supply is shown in Fig.2. The block diagram of quadrupole magnet power supply is also shown in Fig.3. The tracking error among the power supplies was designed within 0.01 % in order to accelerate the injected beam and to cool the stacked beam. In according to the computer simulation³⁾, a self correction method is available in order to attain the tracking error of less than 0.001 %. A precise feedback control of the active filter is performed in order to attain a current stability 0.01 %.

Hardware

A power-supply control system has been developed to perform the pattern generation and self correction. The power-supply control system consists of a distributed microcomputer system based on the MULTIBUS standard. The block diagram of the control system is shown in Fig.4.

The main-computer (MCP) provides a graphic terminal, hard disk and touch terminal. The operating system CP/M-86™ is available on the main-computer. Four set sub-computers (SCP1-SCP4) are provided for the magnet power supplies. Data transfer between the main and sub-computers is carried out through the MULTIBUS. Each of the sub-computer provides an IO controller to regulate the power supply. In the bending magnet power supply, three 16-bit DAC's and two ADC's are provided. The three DAC's are used for the AVR, ACR corrections and an active filter control, respectively.

The two ADC's are used to sample the magnet current and voltage. The DMA controller (i8089) on the sub-computer regulates the data transfer between the IO controller and power supply.

The self-correction of bending magnet power supply is performed as follows. The reference current pattern $I(t)$ is generated by the calculation on the basis of magnetic field measurement. The additional voltage pattern $V(t)$, which is zero during the initial cycle of the operation, is calculated according to the self-correction as follows

$$V_n(t) = V_p(t) + K \{ I(t+t_r) - I_d(t+t_r) \}$$

where V_n , V_p , t , t_r , K and I_d are next pattern, present pattern, time during cycle, response time, gain of the self correction and load current, respectively.

$I_d(t)$ which is read out through the DCCT may include the noise due to an intrinsic ripple of the DCCT. Then, $I_d(t)$ is averaged over the cycle. The response time is defined as a time which is a load current response to an impulse at the $V(t)$ port takes to appear as a maximum peak.

Table 1. Design parameters of the power supplies.

	BMAG PS	QMAG PS
Magnet coil resistance	5 mΩ × 25	51 mΩ × 7
Magnet coil inductance	12.5 mH × 25	12 mH × 7
Cable resistance	20 mΩ	20 mΩ
Cable inductance	10 mH	10 mH
Maximum power rating	1500 kW	80 kW
Maximum output voltage	600 V	200 V
Maximum output current	2500 A	400 A
Operating current	200-2500 A	10-400 A
Current slew rate (di/dt)	657 A/s	533 A/s
Current stability (flat top)	± 0.05 %	± 0.05 %
Current stability (rising)	± 0.4 %	± 0.2 %

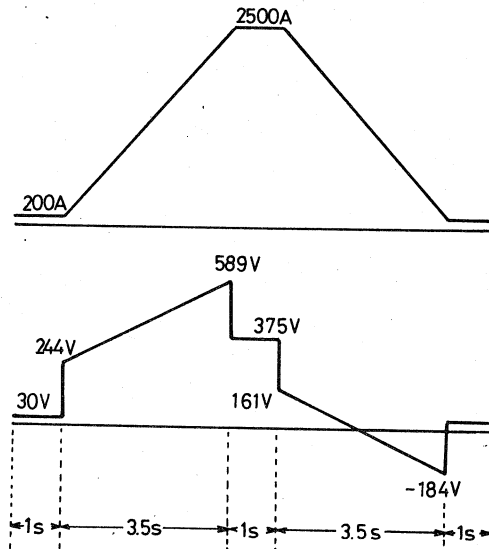


Fig.1 The current and voltage pattern of the bending magnet. Upper shows current pattern and lower shows voltage pattern, respectively. Repetition rate is 0.1 Hz and rise time and fall time of magnet current are 3.5 s, respectively.

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The transferred data for the reference current pattern $I(t)$ and voltage pattern $V_p(t)$ are stored into the foreground area of sub-computer. A background memory area is also provided for the AVR correction data $V_A(t)$ generated by executing the self-correction program. The self-correction is performed so that the sampled data of the magnet current $I_d(t)$ is equal to the reference current pattern $I(t)$ corresponds to the required magnetic field. An execution of the self-correction program is available on the sub-computer while the data transfer is carried out with the aid of DMA controller.

After the execution of the self-correction program, the AVR correction data in the background memory is transferred to the foreground memory during the time between the end of pattern generation and the start of following pattern for which the provided in the foreground memory.

A large-size memory area is required in order to store the many kinds of transfer data. The main-computer has an area of 1 M bytes and the sub-computer an area of 512 k bytes, respectively. The hard disk has an area of 20 M bytes for storing the control program and operation data. The control system also provides the CAMAC controller for the single crate. Sequential control, such as power ON or OFF, is carried out with the CAMAC module. The touch terminal is used to control the power supplies. Console desk operation is take place of finger touch operation on the touch terminal.

Software

The software system of the main-computer is composed of operating system CP/M-86TM, interpreter INSBASIC, macro assembler MA86TM and linker LD86TM. The sub-computer provides the ROM based communication program for the data transfer and execution of interrupt program. The CP/M-86TM is main operating system for the microcomputer i8086. The MA86TM and LD86TM are effectively used to generate the control program worked on the board level computer such as the sub-computer.

The own made interpreter INSBASIC, like the BASIC, consists of the basic functions, user defined functions, system functions written by INSBASIC itself.

The user program is written by INSBASIC. The user defined functions are written by assembler or C-language. The examples of user defined function are CAMAC handler, GP-IB handler and sub-computer handler. The basic functions are composed of general functions such as "print" command, and special functions such as "turn on" command for the power supply. GP-IB operation is performed through the CAMAC.

The user defined functions and system functions are registered when the interpreter is loaded. These functions are executed when the "call" command of the interpreter is issued. The stacked view of INSBASIC is shown in Fig.5. Six layers of this system is capable of develop the software system of TARN-II.

The examination of the user defined function is closely described about sub-computer handler. The control program of sub-computer is developed by the main-computer and down-line loaded to the sub-computer, subsequently. Development of the control program is carried out with the aid of MA86TM and LD86TM. Developed control program is saved into the hard disk and called by the communication program to store them into the sub-computer. The control program is memorized in the sub-computer until the new program is loaded or the power supply of control system become the turn-off. The communication program between them is the SCP driver resident in the main-computer and the SCP-monitor resident in the sub-computer, respectively. Then, the up load and down-load of control data are performed with the aid of this communication program.

The example of program execution at the interpreter mode is described below. The user defined function "hrdchk" executes the pattern generation, data transfer and data compare at the main-computer, respectively. The control program "AAAAAAA.COMD" executes the data transfer between the main and sub-computer, the data handling between the sub-computer and power supply and data compare, respectively.

Before the execution, the control program is loaded by the "dload" command. The "dload" command is one of the user defined function.

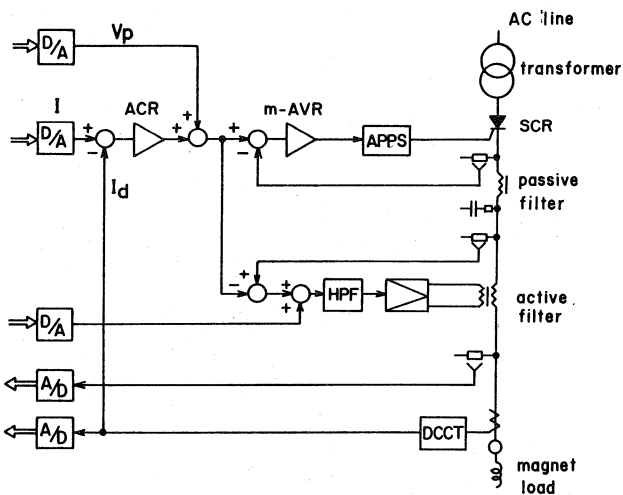


Fig.2 The block diagram of the bending magnet power supply. The 12-phase thyristor valves are regulated by AVR loop and ACR loop. Voltage correction is performed with the 16 bit DAC and reference current pattern is generated by the 16 bit DAC, respectively.

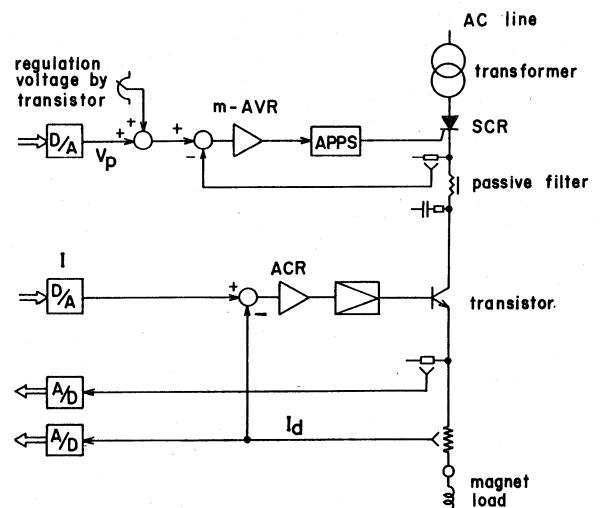


Fig.3 Block diagram of the quadrupole magnet power supply. The 12-phase thyristor valves are controlled to generate the voltage pattern and the series transistor is controlled to regulate the current pattern, respectively.

The writing form is

```
call dload(*.'AAAAAAA.COMD')
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where "*" is the group number assigned for the sub-computers from 1 to 4 and "AAAAAAA" is program name with 8 characters. "COMD" means the object module defined by CP/M-86™.

When the program loading is finished, the prompt of the loading is issued by the main-computer. The initialization of the DMA controller is carried out when the control program "AAAAAAA.COMD" is loaded. The control program "AAAAAAA.COMD" executes the DMA initialization just after the completion of program loading. Then the execution of the data transfer is performed synchronously between them.

After the program loading is completed, program execution is dictated to the sub-computer by

```
call hrdchk(+)
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Subsequently, the interpreter executes the user function "hrdchk". The "hrdchk" generates the pattern data and transfer it into the sub-computer. Data handling through the IO controller is carried out as soon as complete the data transfer. The DMA controller is capable of set the data length, start address of source area, start address of destination area of two groups, respectively. Then, the memory areas are divide by input and output groups of the data handling. After the data handling is completed, the input data from the power supply is up-loaded to the main-computer and compared with the reference data in the sub-computer. The compared result is displayed on the graphic terminal.

The synchronous data handling is carried out with the internal or external clock signal. When the external clock is chosen, the 12th harmonic of 50 Hz is applied from the clock pulse generator. If required, the 24th and 36th harmonics can be set, respectively.

However present program is only used to check the IN and OUT operations through the IO controller, usage of the present program can be improved with the additional functions such as the self-correction.

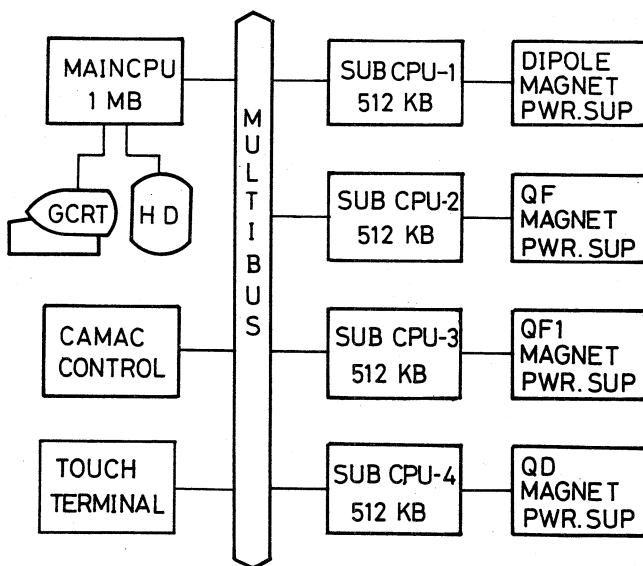


Fig.4 Block diagram of computer control system. The main-computer and four sub-computer are provided for the pattern generation and self-correction. The data transfer between them is performed through the MULTIBUS.

Test of power supply

Construction of the magnet series was finished in 1987 and dc operation of power supplies have been done. The preliminary test of pattern operation have been made to check the IO controller and software system.

Two ADC's and DAC's channels were directly connected and test pattern data was transmitted and received, alternatively. With this test, the electric characteristics and logic control of the control system were basically examined, respectively.

The power feeding from the main bank of power station (3 MVA) is limited by the restriction of power consumption and/or quality of electric power. The improvement of the higher harmonics and/or reactive power are required to operate the magnet power supplies at the maximum rating. Now at well regulated electric power is not available. Then the test of magnet power supply is being carried out at a low power level.

The electric characteristics of the magnet series were measured to evaluate the design parameters. The cable resistance is measured by the voltage drop method using the precise current source. Deviation of the ohmic contact was evaluated and uniformly by adjusting the screw up tork. Heat up due to the ohmic loss was also measured during the current feeding with present power supply.

Acknowledgements

The authors are grateful to the members of the Accelerator Research Division, INS for their discussions and assistance. They thank the assistance of the staff of the computer room, INS in touch terminal development, interpreter development and in designing the power supply control system. The control system for the power supplies was manufactured by Ai Electronics Corp.

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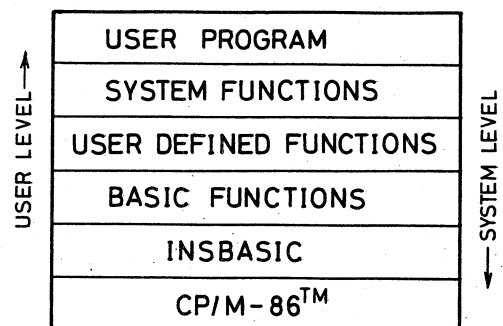


Fig.5. Stacked view of the software system for power supply control system. The user defined functions are written by the assembler or C-language. System functions and user program are written by the interpreter, respectively.