Computer Control of TARN-II Main Ring Power Supply

Shin-ichi Watanabe, Akira Noda, Tamaki Watanabe and Toshiyuki Kohno*

Institute for Nuclear Study, University of Tokyo,Tanashi, Tokyo 188, Japan

*National Institute of Radiological Sciences, Anagawa, Chiba, Japan

The performance and software architecture of a control system of the TARN-II main ring power supply are described. The system provides the trapezoid pattern data to regulate a magnet current with the repetition rate of 0.1 Hz. Data generation and self learning are skillfully performed to attain the tracking error of several 10^{-4}.

1. Introduction

Four sets power supplies have been constructed to excite the main ring magnets of TARN-II. The one is for dipole magnets and the others are for three different functional quadrupole magnets. The current pattern is a trapezoid waveform with a repetition rate of 0.1 Hz. The principal description of the control system is shown in the latest conference[1] and the technical report[2]. This paper then focused on the software and it performance of control system of the existing magnet power supplies.

In the first phase of installation test, full excitation of the main ring magnet have been done with the dc or trapezoid pattern. Full excitation test shows that the power supply of main ring requires well regulated electric power though existing power station can't well suppress the inductive power and higher harmonic current due to the operation of TARN-II. Thus the upper level of excitation current is limited so that the voltage drop due to the excitation of power supply should be suppressed under the allowance level.

In Nov. 1988, first beam experiments was established and 20 MeV proton beam was circulated in the main ring. In this phase, the power supply of bending magnets was operated under the dc mode with the excitation current of 255A however it was designed to feed the 600V, 2500A. After that the acceleration test was performed at the flat top current of 600 A. Test of self-learning is being performed at the above mentioned condition to attain the tracking error of several 10^{-4}. At present this control system is a part of main ring control system which is an one of CAMAC control system of TARN-II.

2. System Overview

Five CAMAC stations are controlled with a central computer,M-16, through the serial-highway system. M-16 is a 16-bit microcomputer with a operating system CP/M-86. Each CAMAC station is equipped with both the type L2 crate controller and auxiliary crate controller so that the CAMAC station is alternatively controlled with either the central computer or local computer system. The main ring power supplies are controlled with this control system. In fig. 1, the block diagram of the CAMAC system of main ring magnet control system is shown together with the pattern generator. The pattern generator can be access through the CAMAC system or auxiliary console.

The pattern generator is composed of the multiprocessor system based on the MULTIBUS-1 standard. The main computer (MCP) is equipped with a graphic terminal, hard disc and serial printer. Four sub-computer(SCP1-4) are provided for the individual pattern control. Each SCP includes the i8086, i8087 and i8089 to execute the arithmetic calculation and DMA operation between the SCP and I/O interface of power supply. In the power supply, the 16 bit DAC's and ADC's are housed in the air conditioned shield box and connected with the pattern generator. The pattern data are transferred from/to the power supply synchronized with the thyrister trigger signal.

The program package , WMGPSC, has been developed to regulate the main ring magnet power supplies. WMGPSC is composed of file loader, file generator, pattern corrector and graphic manager etc. With this program package, pattern generation of the power supply is performed with a convenient procedure. WMGPSC is written in INSBASIC. At present 13 kinds of subroutines are provided for the power supply control system. The following chapters 3, 4 and 5 are described about the details of pattern generator.

3. Theory of Self-learning

Current control of the power supply is subjected to the combination of precise DA-converters. The control data of the DA-converter is generated by the microcomputer M-16 or pattern generator itself. In the microcomputer, new control data of magnet power supply is generated by the self-learning program given by the following allegorizm

$$Vn=k(Ir-Im)+Vp, \quad (1)$$

$$In = k(Ir-Im)+Ip, \quad (2)$$

where Vn, k, Ir, Im, Vp and Ip are next voltage, gain, reference current, measured current, present voltage and present current, respectively.

In the equation (1), initial condition of the pattern data is provided as the reference data Ir and Vp. Equation (2) is available for the self-learning system of the Q magnet power supply. It is considered that the difference of Ir and Im is to be shrink to nothing with the aid of self-learning program. The reference data of the bending magnet is composed of sequential data train of Ir,Vp and Vf. The current data, Ir, is 16 bit binary data and voltage data, Vp and Vf, are 16 bit two's complement data. Vf is filter correction voltage. On the other hand, the measured data is also composed of sequential data train of Im and Vm.

The trapezoidal pattern data is divide by 5-sections, series of flat base, rising, flat top, falling and flat base. Each section is smoothly connected with a time-square dependent curve. The time-square dependence is given as

$$di/dt=\alpha\, t, \quad (3)$$

where α is determined by $(di/dt)_{max}/t_{max}$. The constant $(di/dt)_{max}$ results in an output voltage of L*di/dt. In the case of repetition rate of 0.1 Hz, the constant t_{max} and di/dt_{max} are chosen as 0.1 sec and 756 A/s, respectively.

The pattern generation is carried out with the program 'IBPAT.CMD' where is written in FORTRAN. IBPAT.CMD generates the binary data with above mentioned data structure. It was considered that generated pattern data may include the error of gain and offset of the DA converter for the power supply. Maximum data length of the reference pattern is FC00h byte. Generated data is saved into the hard disc with the fixed file name. In the self-learning module, control program refers the reference pattern data in order to calculate the corrected pattern data.

Minor correction of the flat base current is required to adjust the injection energy. It is a convenient way to adjust a flat base current with the DC correction program 'IDCSET'. After that, pattern data is calculated on the basis of skillful adjustment of closed orbit and β functions. The calculated data is saved into the hard disc. In the acceleration mode , correction of Q magnet current is carried out with the same manner to keep the constant ν . It is assumed that constant ν is insured by keeping the ratio of Q magnet currents among them. The excitation current of Q magnet currents IQ_d, IQ_{f1} and

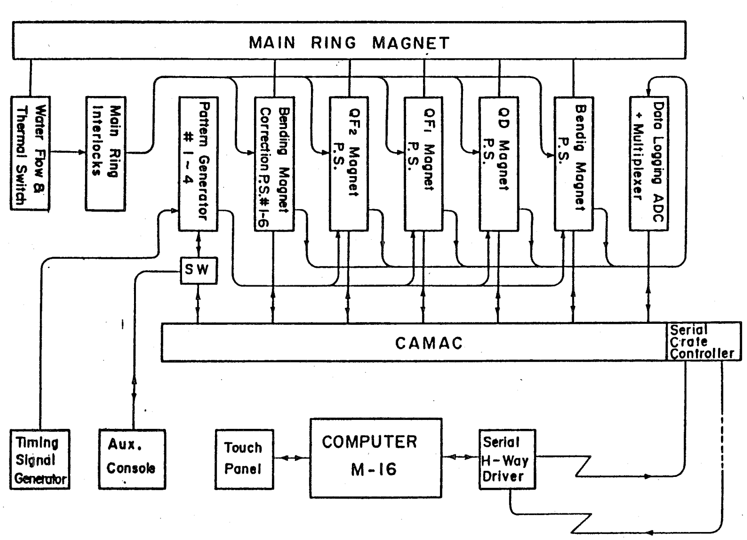

Fig. 1 Main Ring Power Supply Control System

IQ_{f2} are regulated with the dedicated sub-computer control system.

4. Result of Self-learning

Two ways of data correction are available in the existing control system. The one is subjected to the sub-computer (SCP) and the other is employed in the main-computer (MCP). In the SCP, exchange of the pattern data is performed only in the random access memory (RAM) area of SCP in order to save the calculation time. Self-learning program may includes the floating calculation with coprocessor (i8087) to calculate the compensation term due to the difference of Ir and Im. The control program of SCP including the arithmetic calculation is written in macro-assembler. In this program, identification of the attainment is performed to find out the value of difference of Ir and Im which is passed trough the gate value of the tracking error.

The same manner of self-learning is carried out in the MCP. The self-learning program is provided as a subroutine of the INSBASIC. The subroutine is called from the main program and executed subsequently. Result of calculation is down-loaded to the SCP and hard-disc if required. This method has a merit to adjust a fine parameter(s) of the execution program. In the data processing program, digital filtering technique is necessary to eliminate a pulstic noise due to the change of thyrister bank or others. We have a slide-scale type digital filtering program.

Beam acceleration is subject to whether measured current is well fit to the original pattern data or not. On behalf of dedicated measurement system the power supply control system comprises an evaluation program.

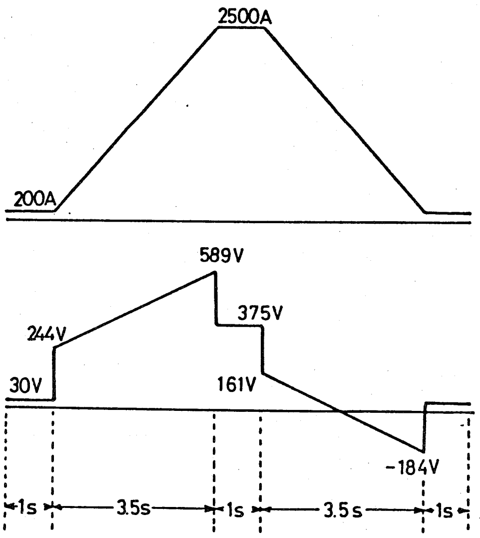

Fig.2 Example of Original Pattern Data

The evaluation program deals with the original pattern and measured pattern data. Graphic-display terminal VT140 is 600 X 400 dots color display terminal which is composed of 14" color TV, video RAM and RS232c terminal. Tracking error of excitation current is calculated and displayed on the VT140. Data stream of the ASCII code is sent to the VT140 to show the pattern data or tracking error. The VT140 accepts the escape commands to show the graphic data. Data speed is 9600 baud. In the VT140, display area of 500 X 300 dots is occupied to show the pattern data. Since a drawing speed depends on the number of dots, drawing density is chosen with the argument of graphic subroutine. In figure 2, example of the original pattern is shown. Measured data or original data is uploaded from the SCP and displayed on the VT140 after the data processing.

5. Conclusion

Multi-microprocessor system is a feature of this pattern generator for main ring power supplies of TARN-II. On behalf of the developed system the excellent system which is composed of network system was considered. No difference between the both system was discovered because the distributed system is necessary to regulate the multi-port power supplies. But the difficulty of system development was presented to us because the high power, high technology and high risk are included in these systems. Developed system is being worked nevertheless excuse from authors are issued. In the near future, we must try the self-thinking control system which is similar to the AI system.

Acknowledgments

The authors express their thanks to Prof. Y. Hirao and K. Sato for their continuous collaboration who left INS to National Institute of Radiological Sciences recently. They also thank Mr. Aoki for his work concerning the design of digital filter and Mr. Chiba for his aid concerning the development of INSBASIC.

References

(1) S.Watanabe et al, " Power Supply Control System for TARN-II Main Ring Magnet System" Proc. of 6th Symp. on Acc. Sci. and Tech. 1988, 242.

(2) M.Takanaka and S.Watanabe "Decision of the Circuit Parameters of the High Tracking, Low Noise Power Supply for the Bending Magnet of TARN-II" INS-T-456, March, 1986.