Particle Accelerators, 1990, Vol. 29, pp. 127–132
Reprints available directly from the publisher
Photocopying permitted by license only
© 1990 Gordon and Breach, Science Publishers, Inc.
Printed in the United States of America

PERFORMANCE OF THE TRISTAN MAGNET POWER SUPPLY SYSTEM

HITOSHI FUKUMA, ATSUSHI KABE, TOSHIYUKI OZAKI, YASUNOBU OHSAWA, TADASHI KUBO and KUNINORI ENDO
National Laboratory for High Energy Physics
1-1 Oho, Tsukuba-shi, Ibaraki-ken, 305, Japan

Abstract Performance of the magnet power supplies of the TRISTAN main ring (MR) and the accumulation ring (AR) and improvement of power supply control system are described.

INTRODUCTION

The TRISTAN accelerator complex has two storage accelerators, the main ring (MR) and the accumulation ring (AR). The MR of 3018 m in circumference accepts the positron and electron beam from the AR at the energy of 8 GeV and accelerates them to 30 GeV to deliver the beams to electron-positron colliding experiments. The time interval during acceleration is 2.4 minutes and that at the top energy is 1.5 hours. The AR accelerates the electron or positron beam from the 2.5 GeV linac and transfers the beam of 8 GeV to the MR. The beam is accelerated in 20 seconds. During the colliding experiments at the MR, the AR is operated as a storage ring to deliver the beam to various purposes such as research with synchrotron radiation , accelerator study for a colliding beam experiment and development of detectors with gamma ray from the internal target.

Similarity of the operation between the AR and the MR allowed to fabricate power supply systems of the AR and the MR under the same concept. They have been operated more than 5 years without serious troubles. In this paper performance of power supplies and improvement of power supply control system will be treated with brief description of the system.

POWER SUPPLIES AND POWER SUPPLY CONTROL[1]

The number of the power supplies is 606 for the MR and 140 for the AR. They are distributed among 10 site buildings, 8 for the MR and 2 for the AR. All power supplies are operated receiving digital input data as the current reference. The digital data are converted to an analogue signal with a digital to analogue converter (DAC) and compared with an output current for a feedback control. The main power supplies, that is the power supplies of bending and quadrupole magnets, take both current and minor voltage feedback loops. The specifications of the main power supplies of the AR and the MR are summarized in Table I.

TABLE I Specifications of the TRISTAN power supply system[1]

	AR			MR			
	B	QF,QD	Local Q	B	BW	QF,QD	Local Q
Primary voltage(V)	3ϕ-6600	3ϕ-420	3ϕ-420	3ϕ-660	3ϕ-420	3ϕ-6600	3ϕ-420
Rated dc current(A)	1900	1340	1340	1500	20	1350	1500 ~1700
Rated dc voltage(V)	1700	170	38 ~ 80	4x1068	180	2x908	47~206
Rectification	24p-SCR	12p-SCR	12p-SCR	24p-SCR	6p-SCR	24p-SCR	12p-SCR
Current regulation	SCR pc & filter	SCR pc & trans.	SCR pc & trans.	SCR pc & filter	SCR pc & trans.	SCR pc & filter	SCR pc & filter
Cuurent detection	DCCT	DCCT	DCCT	DCCT	DCCT	DCCT	DCCT
Current stability	$<10^{-4}$	$<10^{-4}$	$<10^{-4}$	$<10^{-4}$	$<10^{-4}$	$<10^{-4}$	$<10^{-4}$
Input data(bits)	16	16	16	16	16	16	16
No. of circuits	1	2	23	1	1	2	76
No. of magnets	56	28	58	264	8	192	200

B = normal bend, BW = weak bend, QF, QD = normal cell quad
pc = phase control, trans. = transistor control, filter = dc & active filter

All power supplies are controlled by 5 minicomputers which are connected with the TRISTAN control computer network. Among them 4 minicomputers are assigned to the MR. The power supplies are interfaced to the minicomputers by CAMAC modules.

Each wave form of the current references generated by the minicomputer is stored in a memory module which has a random access memory of 20 bits x 16 kw . Out of 20 bits ,16 bits are available for the current reference, 3 bits for distinguishing the operational status of the accelerators such as injection, acceleration and flat top and 1 bit for the parity. An amount of data for one accelerator cycle is 14.7 kw for the MR and 4.8 kw for the AR and the generation time of all the wave forms is about 20 minutes for the MR and 11 minutes for the AR.

The current reference in each memory module is transferred to the power supply synchronized with clock pulses. The clock pulses are sent out to the power supplies via timing module. The timing module works as the gate of the clock pulses which is opened or closed by event pulses from the accelerator timing system so as to assure the synchronized operation of the power supplies.

PERFORMANCE OF POWER SUPPLIES

All the power supplies were tested in a factory of a manufacturer. Furthermore acceptance tests were performed for the individual power supply in our laboratory under actual environment. Here the performance of the main power supplies is presented.

Statistical distribution of stability for the main power supplies of the MR and the AR are plotted in Figure 1 and 2 respectively. The

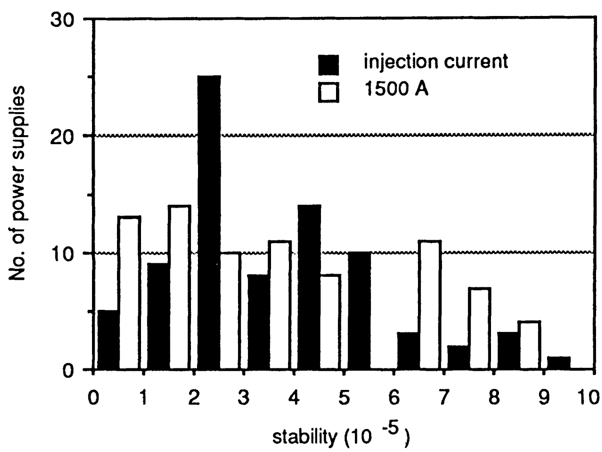

FIGURE 1 Statistical distribution of stability for the main power supplies of the MR.

stability is defined as the ratio of the maximum variation of the output current to the output current itself. The measurement of the stability was performed through more than 8 hours for the main power supplies of the MR. For those of the AR the measurement time varied from 1 hour to 8 hours among the power supplies.

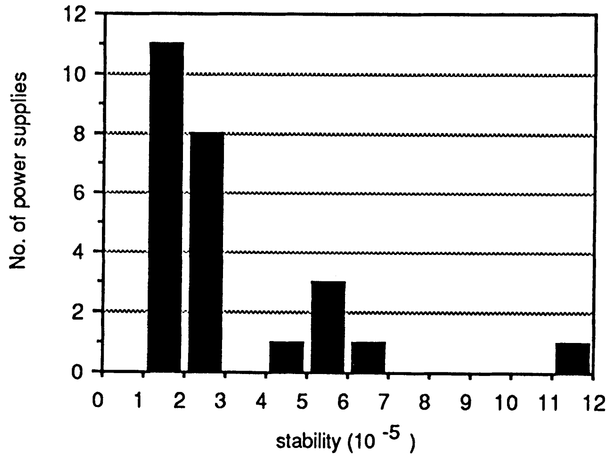

FIGURE 2 Statistical distribution of stability for the main power supplies of the AR.

A ripple current of the main power supplies of the MR was measured by a search coil in a bending magnet which was connected to a power supply for the performance test. Statistical distribution of the ripple current divided by the output current for the main power supplies of the MR is shown in Figure 3. For the main power supplies of the AR, the ripple current I_r was calculated from the output voltage ripple V by the following formula; $I_r = V / Z$, where Z is an impedance of a load at 50 Hz. The ratio of the rms ripple current to the output current was less than 1 x 10^{-5} for all the power supplies of the AR.

The time lag of the output current behind the current reference was obtained by measuring the difference between the output voltage of DAC and that of DCCT which is used for the current detection of the current feedback loop. The time lags of the main power supplies of the MR scattered from 23 ms to 47 ms and that of the AR did from 1 ms to 36 ms. The difference of the time lag of each power supply is corrected at the calculation of the wave form of the current reference to make identical the time lag of the output current for all the power supplies.

The response of each power supply to external disturbances was examined. As an example, the result for the power supply of defocusing quadrupole magnets in normal cells of the MR is shown in Figure 4. The upper line is the difference between the output voltage of DAC and that of DCCT which is described before. The lower line is the variation of the primary voltage of 6.6 kV. The various disturbances are shown in this figure. During the measurement the output current was 162 A.

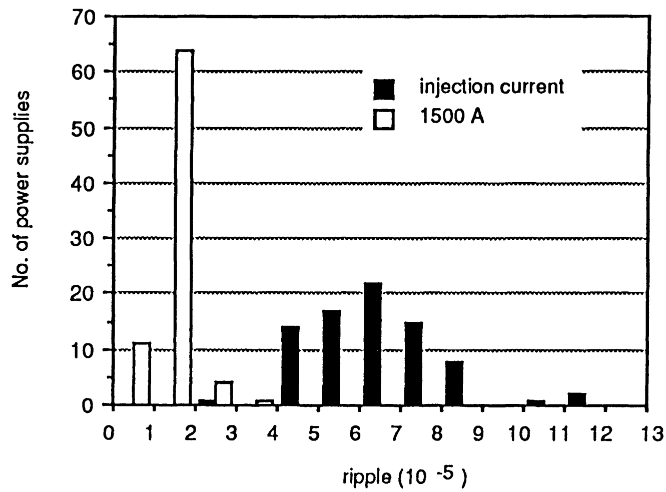

FIGURE 3 Statistical distribution of the ripple current divided by the output current for the main power supplies of the MR.

IMPROVEMENT OF POWER SUPPLY CONTROL

On the operational experience during past five years, some improvements were made to the power supply control.

1) All the memory modules of the AR were replaced with new ones. As described above the AR is operated for various users in the interval of the beam filling to the MR. As the different users require the different energies and optics, the wave form of the current reference should be changed without considerable loss of time. This problem was solved by increasing the memory area of the memory module from 16 kw to 64 kw

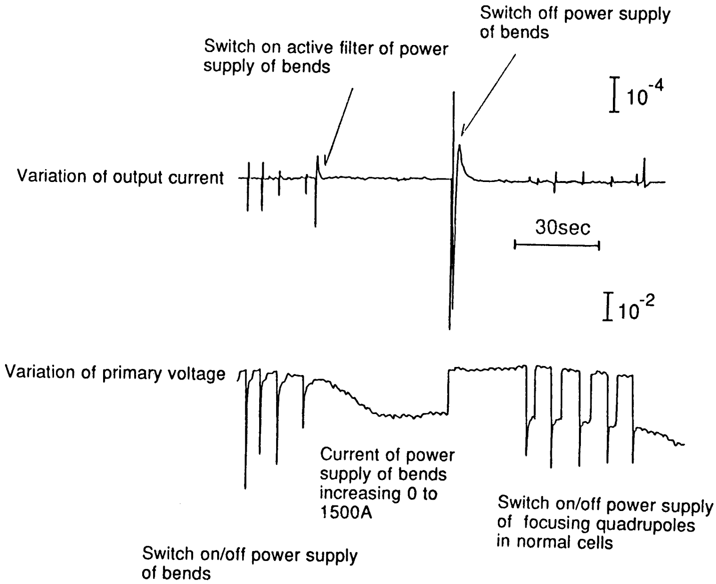

FIGURE 4 Response of the power supply to external disturbances. The examined power supply is that of defocussing quadrupoles in normal cells of the MR.

and storing many wave forms in the module. At present seven wave forms are used for the daily operation of the AR. The amount of the memory which is allocated to a wave form is 7 kw.

2) At the beginning of the operation of the AR the clock pulses were supplied by a module of the accelerator timing system. But from the operational experience of the AR this module was replaced by the specially developed clock generator module which enables us to change the clock rate and to start or stop the generation of the clocks. The clock generator module is useful on tuning of the accelerators, as it makes possible to change the acceleration time and to retain an arbitrary beam energy during acceleration without rewriting the wave forms in the memory modules.

REFERENCES

1. H. Fukuma, A. Kabe, Ta. Kubo, T. Ozaki and K. Endo, Proc. of the 1987 IEEE Particle Acc. Conf.,Washington, D. C.,1529 (1987)