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Full Power Operation of a Synchrotron Magnet Power Supply in Dual Resonant Frequency Mode

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ABSTRACT

A synchrotron magnet power supply aimed at practical use was constructed and successfully operated in dual resonant frequency mode. A magnet exciting current was 1300A, and values of resonant frequency were 100/3Hz for acceleration period and 100Hz for magnet reset period, respectively, resulting in an average frequency of 50Hz.

INTRODUCTION

A dual resonant frequency circuit for a synchrotron magnet system was first proposed by M. Foss and W. Praeg.[1] In their circuit two frequencies were alternated each other by switching a part of the resonant capacitor with an inverter type thyristor. This operation utilizes most of accelerator cycle for beam acceleration and consequently reduces the RF accelerating voltage which is required in single frequency operation.

Our circuit is the similar one but the thyristor is replaced by a gate-turn-off thyristor (GTO). Alternative frequencies were chosen 100/3Hz for acceleration period and 100Hz for magnet reset period, respectively, so that average frequency of 50Hz was obtained. The behavior of the circuit has been studied with a model circuit,[2] and feasibility of this circuit was confirmed. Taking account of the results, we constructed the magnetic power supply aimed at practical use. In the present paper, we describe its performance.

CIRCUIT DESCRIPTION

The resonant system is illustrated in Fig. 1, and parameters of the circuit are listed in Table 1. This circuit consists of two parts; the dual resonant frequency circuit and a pulse power supply. The pulse power supply feeds the power consumed in the resonant circuit with a pulse current at each acceleration period. The basic performance of the resonant circuit was described elsewhere[2] . For the present circuit, in order to protect the GTO against large forward voltage drop, we replaced the diode, which was used in the model circuit, by a thyristor denoted by SCR_g in the figure. The switching timing of the SCR_g is made to coincide with the GTO.

A snubber circuit is composed of a diode Ds, capacitor Cs and registor Rs. When the GTO is turned off, Cs begins to absorbs the GTO current through Ds. After the capacitor voltage reaches maximum, the capacitor Cs discharges through Rs. This action suppress the rapid rise of the voltage across the GTO and ensures its safety operation.

Fig. 2 shows waveforms of the magnet voltage, magnet current Im and the GTO current Ig when the system was operated with maximum rating. Here, amplitudes of the magnet voltage and current were 2800V (at 100Hz) and 1300A, respectively. The maximum current through the GTO was observed to be 1200A. Current waveforms of the GTO, the resonant capacitor C1 and the magnet for one accelerator period are shown in Fig. 3. A damping oscillation of 2.5kHz is observed in the capacitor current

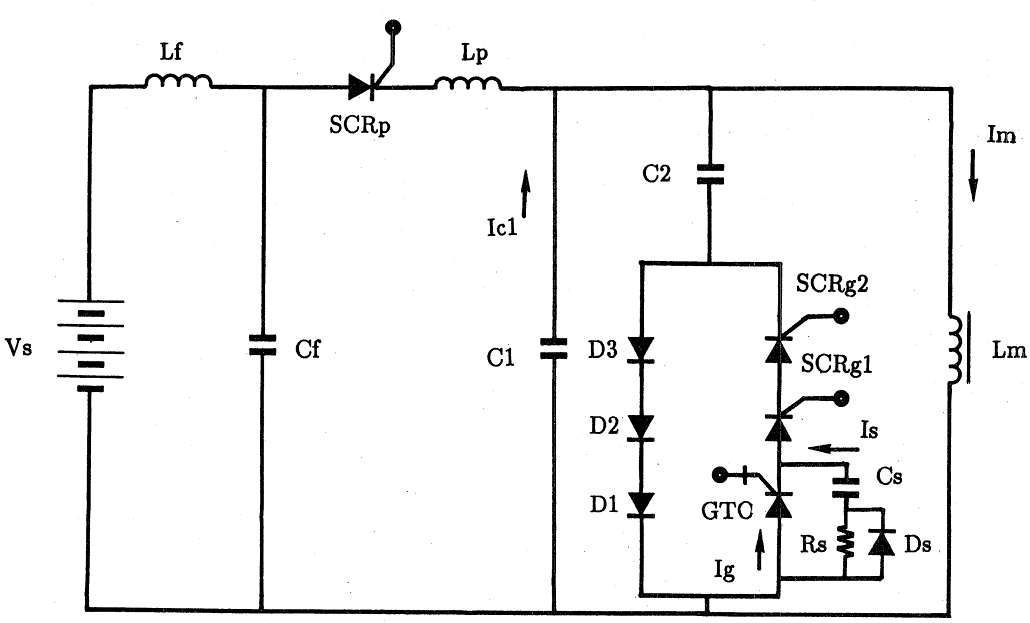

Fig. 1 Diagram of the resonant system

I_{C1} at the beginning of the acceleration period. This phenomenon is caused by an alternative current between capacitors C1 and C2. The effect due to this oscillating current was observed like a dip on the waveform of the magnetic field, as shown in Fig. 4. This disturbance amounted to 0.4% of the amplitude of the magnetic field.

Table1

Parameters of Dual Resonant Circuit

- Pulse power supply -	
DC power supply Vs	1100V
Capacitor Cf	Capacity 93.4μF
	Peak voltage 2200V
Inductor Lf	Inductance 1.73H
Inductor Lp	Inductance 12mH
Thyristor SCRp	CR100AL-24(HITACHI)
	100A/1200V
- Dual frequency system -	
Capacitor C1	Capacity 859μF
	peak voltage 3300V
	peak current 1800A
Capacitor C2	Capacity 6870μF
	peak voltage 1100V
	peak current 1600A
Magnet Lm	Inductance 2.9mH
	peak voltage 3300V
	peak current 1800A
Diode D1 to D3	C01DA(HITACHI)
	800A/3000V
Thyristor SCRg	CA01CF(HITACHI)
	1000A/2500V
GTO thyristor	GFP2000B25(HITACHI)
	peak off-state voltage 2500V
	rms-on-state current 800A
	Controllable on-state current
	in repetitive case 2000A
	peak on-state voltage 2.5V at 2000A
- Snubber circuit -	
Capacitor Cs	Capacity 6μF
Registor Rs	Resistance 2.3Ω (800W)
Diode Ds	DFS80B17
	80A/1700V

At the end of the acceleration period, sharp disturbance on the magnetic field is seen as shown in Fig. 5. This disturbance was also observed in the voltage and current waveforms of the magnet at the same time. Therefore, there may be some origin although it is not confirmed. Such a deformation of the waveform was estimated to be 2.7% of the amplitude. Fig. 6 shows the waveforms of the snubber current Is and the GTO current Ig when the GTO turns off. While the GTO current turns off within 2μsec, the snubber current decreases more slowly. Total amount of the turn-off time of the current of the branch containing the GTO was about 20μsec. It is, however, sufficiently enough for our circuit, since the average repetition rate is 50Hz.

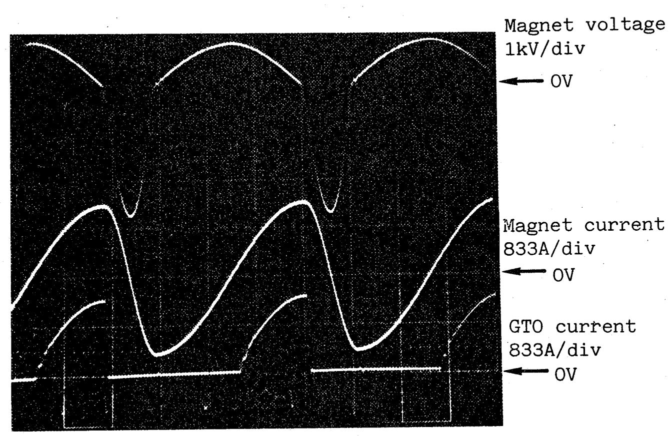

Fig. 2 Voltage and current waveforms of the magnet and GTO current

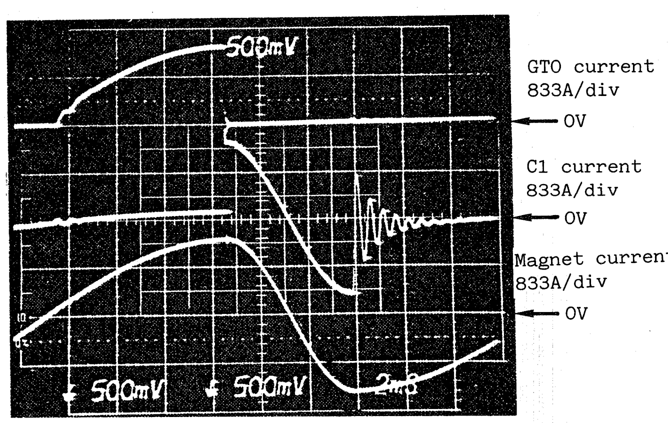

Fig. 3 Current waveforms of GTO, C1 and Magnet

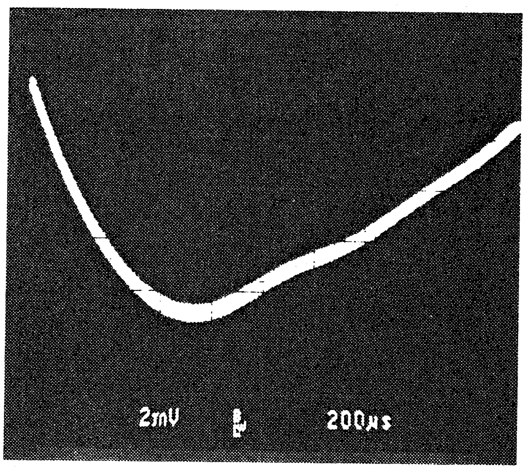

Fig. 4 Waveform of the magnetic field around the beginning of the acceleration period

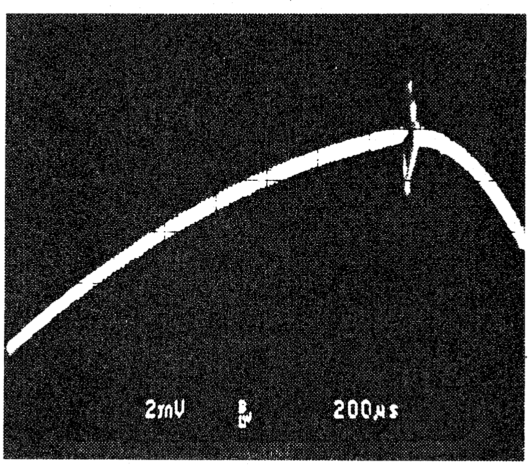

Fig. 5 Waveform of the magnetic field around the end of the acceleration period

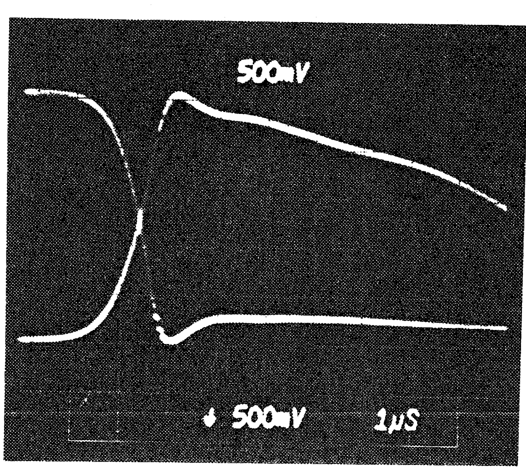

Fig. 6 Current waveform of GTO and snubber circuit

SUMMARY

An operation of the dual resonant frequency circuit aimed at practical use was performed successfully. The magnetic field suffers some disturbances at extremes of the acceleration period. At the beginning of the acceleration period, fortunately, it is negligible practically with respect to the amplitude of the magnetic field. However, some consideration may be needed to avoid an error field at the end of the acceleration period. In order to achieve the excitation of the synchrotron magnet, a dc-magnetic field is needed. Therefore, we are preparing a dc-power supply and a choke transformer which is used for superposition of ac and dc-current.

ACKNOWLEDGEMENTS

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REFERENCES

1. M. Foss and W. Praeg, IEEE, Trans. Nucl. Sci., NS-28, 2856 (1981)
2. H. Someya et. al., IEEE, Trans. Nucl. Sci., NS-32, 3775 (1985)