PROPOSAL OF A NEW TYPE OF RESONANT POWER SUPPLY FOR SYNCHROTRON RING MAGNETS

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Abstract

This paper proposes a new scheme of resonant-type synchrotron ring magnet power supply. The link point is that using switching devices (thyristors or diodes etc.) alters the directions of discharging and charging of the resonant capacitance. The all system is powered by low voltage DC power supply(-ies), the high voltage needed by the varying current in the load inductance is automatically generated in the system's working process. The wave forms of the load current are with flat bottom and with or without flat top. A method of making the load current fall fast by using series/parallel of capacitors is given. In this paper some examples are given and they are calculated by MICRO-CAPIII program.

1 INTRODUCTION

Conventionally, synchrotron ring magnet power supplies adopt resonant system with DC-bias[1,2,] or phase-controlled rectifiers[3]. The former, mostly used for fast-cycling synchrotrons, requires high precision of resonant frequency, and the repeat frequency can not be adjustable. The merit is that it eliminates the requirement of having to provide a large amount of reactive power. The latter mostly used for slower-cycling synchrotrons, it needs a large amount of reactive power compensation, but the load current wave forms and the repeat frequency can be varying, Another, namely "dual resonant power supply"[4], can produce flat top and flat bottom current pulse, is only confined to theoretical analysis, experimental research and project design. So far there has been no report that it is used in a practical machine.

All of those above have to be provided with high voltage power for the varying current in the large load inductance.

In order to overcome the defects of the several types of power supplies above, this paper proposes a new type power supply. Its advantages are that the reactive power is eliminated, the reactive components are reduced, the circuit is simple, the load current wave forms are pulses with flat bottom and with/without flat top, the repeat frequency is adjustable, and they need not any high voltage power, need no tuning, and are suitable for fast and slower cycling synchrotrons.

The power supply related in reference [5] is powered by low voltage, but its use is very limited and the power supply this paper proposed is much different from it.

In this paper some design examples are given. All the examples (synchrotrons are available or will be constructed in the world) are calculated by MICRO-CAP III program.

2 FUNDAMENTAL PRINCIPLE

This type of power supply is termed Synchrotron Ring Magnet Power Supply (SRMPS), Fig.1. is its fundamental principle diagram. LM, RM is the inductance and resis-

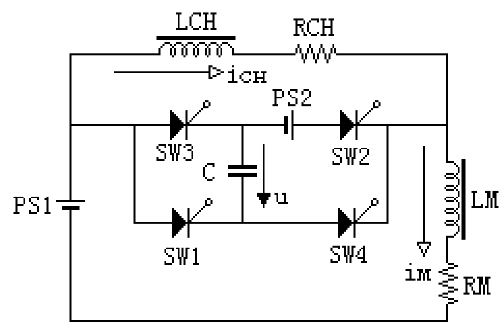


Fig.1. Fundamental Principle of the SRMPS

tance of the load magnet respectively, LCH, RCH is the inductance and resistance of the choke. PS1 and PS2 are DC power supplies, SW1, SW2, SW3 and SW4 are switches (thyristors or diodes or other types of switches). C is the resonant capacitance.

In some cases, especially for fast-cycling synchrotrons, in order to reduce the working cycle, the fall time of the load current have to be compressed. For this purpose, the C can be divided into n parts, each part is C/n, and plus 3(n-1) diodes, thus ensuring that when discharged (in rise period) the n parts in parallel and charged (in fall period) in series. Then the fall time will reduce approximately to one nth. (see Fig. 2).

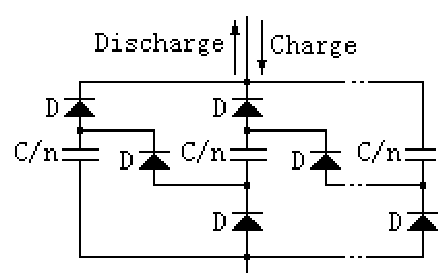


Fig. 2: Diagram of Discharge /Charge of n (C/n) s in Series/Parallel

For a large synchrotron, its ring magnet power supply system can be divided into many cells, called a distributed circuit. Fig. 1 shows one of the cells.

LM, RM are known quantities. The flat top (or peak) value of the load current, marked as "i_T", the bottom value, marked as "i_B" and the minimum repeat cycle, T_{min} (or parameters related with it) are design requirement values.

PS2 is only used for the case in which the cycling is slower and the load current with flat top.

If there is only one cell (for small synchrotrons) and the flat bottom current is equal to zero, the choke does need not to use.

The working process of the system is described as follows:

Before the system begin to work and in any flat bottom period, $i_M = i_{Ch} = i_B$. Suppose, in the flat bottom period of some cycle, u = U (before the first cycle, U = 0), after SW1 and SW2 are turned on, C discharges resonantly with the paralleled inductance of LM and L**C**H, i_M rises. When u discharged to a certain negative value, SW3 is turned on, SW1 off, and then SW4 on , SW2 off, C charged again, and i_M falls. When i_M, i_{CH} go back to i_B, the current flowing through SW3 and SW4 is zero, SW3 and SW4 are turned off. C is charged to U'. Because the DC power supply(-ies), provide energy, so in some cycles of the system starting to work, U'>U, i.e., the charging voltage of C is getting higher cycle by cycle. After a transient period (a number of cycles) the providing energy by the DC power supply(-ies) is equal to the energy loss in the cycling process, the cycle enters steady status.

Under some conditions, during the period between SW3 on, SW1 off, and SW4 on, SW2 off, the load current is at "flat top". Under other conditions, or the period mentioned above is short enough or equal to zero, the current is without flat top.

3 COMPUTER MODEL CIRCUIT

Fig. 3 is the calculation circuit by MICRO-CAPIII. Each

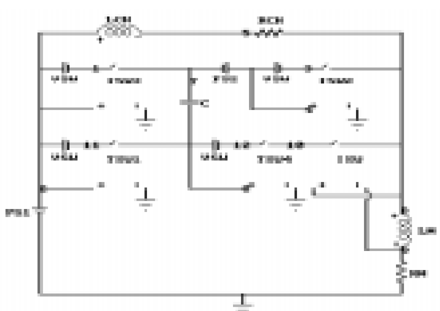


Fig.3 Computer Model Circuit by MICRO-CAPIII.

SW is modeled by a time controlled switch and a battery in series, SW4 is added a current controlled switch in series. The computer model circuit for example 4 is a little different from Fig.3, the resonance capacitor bank has to be altered in accordance with Fig.2 (n=3).

4 SOME EXAMPLES

Four examples are calculated by MICRO-CAPIII.

- Example 1 The booster bend magnet power supply of Shanghai Synchrotron Radiation Facility (SSRF).
- Example 2 The ring magnet power supply of a 500 MeV synchrotron at Argonne National Laboratory (ANL)[5].
- Example 3 The Bend Magnet Power supply of the KEK 12 GeV Proton Synchrotron[3].
- Example 4 The power supply for a future 60 GeV, Kaon factory accelerator in Las Alamos[4].

The related parameters and simulated results by MICRO-CAPIII of them are showed in Table 1 and Figure 4.

Table 1 The related parameters and simulated results

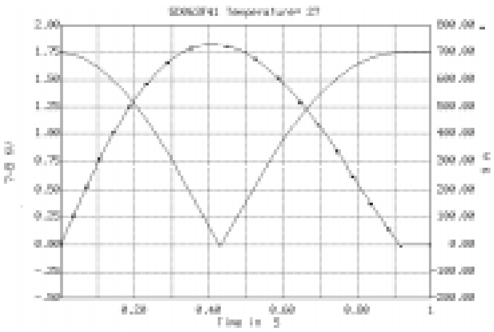
	Example 1	Example 2	Example 3	Example 4
i_T (A)	728.6	3600	2850	10000
i_B (A)	0	1000	200	1040
T (sec.)	1	.032	4	.3
LM (H)	.6789	.0228	1.1	.034
RM (Ω)	.7223	.081	.75	.005
LCH (H)	1E12	.0518	7.89	.58
RCH (Ω)	1E12	.191	5.38	.0851
C (F)	.12	.005	.328	.07041
n	1	1	1	3
PS1 (V)	418.6	270	1228	100.4
PS2 (V)	0	0	929.5	
VSW (V)	1.5	6	4	6
VD (V)				6
TSW1	T0/.431/0	T0/14/-3	T0/.79/0	T0/7.5/-2
TSW2	T0/.431/0	T0/14/-3	T0/2.79/0	T0/22.5/-2
TSW3	T.431/1/0	T14/32/-3	T.79/4/0	T7.5/30/-2
TSW4	T.431/1/0	T14/32/-3	T2.79/4/0	T22.5/30/-2
ISW	I0/800/0	I1.02/5/3	I2.03/30/2	I.112/1.2/4
U (V)	1742	6667	4792	6379

Note: "LCH = 1E12H, RCH = 1E12", mains that the choke does not exist., and "PS2 = 0 V", mains PS2 does not exist.

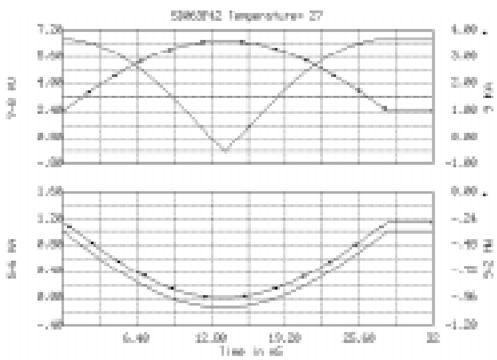
In the tentative programme of example 1, the total inductance and resistance is 0.6789H and 0.7223Ω. The current wave form is triangle, from 0 A to 728.6 A, the rise time and fall time is the same and equal to 0.45 sec., the cycle is 1 sec. In accordance with above data, the output voltage of the power supply is from -1099.2V to 1625.5V.

In all the four examples, thyristors are used for the SWs. In example 3, the SW3 must be compelled to turn off.

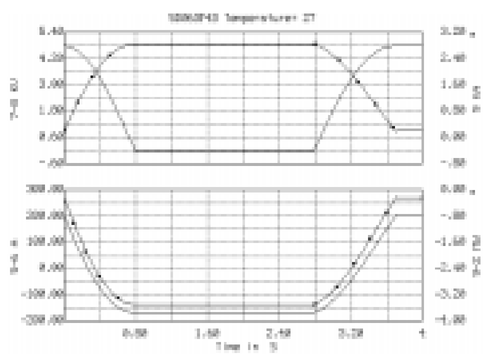
The low half of (b), (c), (d) of Fig. 4 is the wave forms of the choke current and PS1 power. The wave form of PS2 Power of example 3 does not be calculated. If do this, a small resistor has to be added in series with PS2.



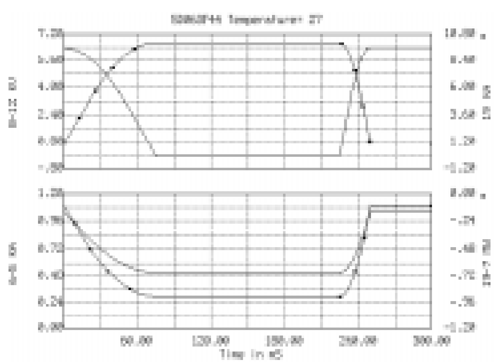
(a) for example 1



(b) for example 2



(c) for example 3



(d) for example 4

Fig. 4 The wave forms of u and i_M

5 CONCLUSION

A new type synchrotron ring magnet power supply has been proposed in this paper. The circuit is simple and applicability is wide. The outstanding peculiarity are that the resonance is free oscillation, there is no any harmonic, and that the high voltage needed by the varying current in the load inductance is generated automatically, so, there is no need to power high voltage and no need to tune in every application cases. In example 4 , it is most complex for thyristors in series/parallel to be used for the SWs. This could be accomplished in reference [4], there should be no problem for all the four examples in this paper.

6 REFERENCES

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