EXTERNAL ENERGY DUMP FOR SUPERCONDUCTING MAGNET OF THE UNI-POLAR POWER

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Abstract

This thesis focuses on the design of superconducting discharge energy circuit structure in Uni-polar power supply [1-3]. Superconductivity is an electrical resistance of exactly zero which occurs in certain materials below a characteristic temperature [4]. It's operation at the steady state in constant temperature area. When Rise up resistance and temperature of superconductivity will have been dissipates function. Uni-polar power supply has needed to design discharge energy circuit when superconductor reduces the current. To make use release the energy transfers to external circuit keep the constant temperature with the superconductivity. The superconducting coil wingding has a total length magnetic period of 56.56cm, total magnet length of 478.9cm and vertical (horizontal) magnetic field of 18.7T.

INTRODUCTION

More and more of the biology and nano-science research is applied the superconducting provide electronic light source [5]. But the light source must keep a high precise current at operation steady state. General the current precise have micrometer lever must be requirement. Due to the magnet load condition when power electrical current reduce, but the magnet current cannot variation current instantaneous. Therefore, use the Uni-polar power supply to replace the bipolar power supply must be needs a design dump energy circuit in power state. To quickly limit the fault current to a value variation than the system can be safely [6].

Additional the freewheel resistor to protect the system when power supply reduce the electrical current. Magnet energy will discharge in resistor to assure the power supply safely and effective. The system setting slew rate 0.3A/s increase and reduces current. The stored energy is 414J with an operation current of 310A, the magnet leakage resistor is 4.18mH.

UNI-POLAR POWER SUPPLY OPERATION THEORY

Uni-polar power supply electric circuit construction as shown Figure 1. When the Conduction diode(D_c) turn on, freewheel diode (D_f) reverse bias. At this moment, the input energy transmission to the magnet, magnet current will linear increase until to the magnet to get into the steady state (solid red line). Oppositional, Uni-polar power supply reduce the current, magnet current will to keep a constant current value and have not the ability reduce to setting current. Therefore, Add the freewheel diode to parallel the magnet to reduce the current when the power supply change the value freewheel diode (D_f) forward bias because inductor current cannot verity at instantaneous and magnet energy will discharge in R_f resistance (broken blue line).

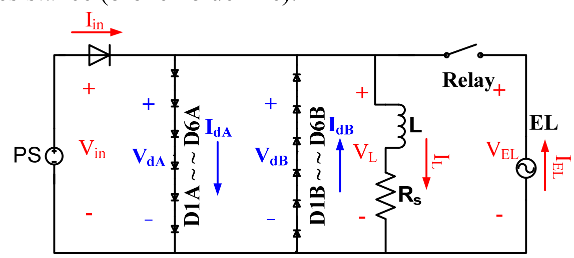

Figure 1: Superconductor with Uni-polar power supply (add the freewheel diode).

CONTROL LOOP FUNCTION BLOCK AND DESIGN

Expect use to the freewheel diode to protect the circuit, in additional to APG current measurement to improve the system stability. The signals to obtain for chroma 62150H-40 APG, for APG current measurement (AIO_MEAS), the devices output analog voltage 0~10V that maps to the actual current is 0~300A.To use the APG signal, V- through the diode and RC circuit. Diode can provide a voltage gap and RC create a delay time. Compare V- and V+ passing the compactor have a control signal V_c. The switch (S1) will turn on when the V+ higher than V-, Inductor energy will discharge to R2. Opposite, Compactor will provide the low level signal when the V+ lower than V-, switch (S1) will turn off and discharge circuit is open. The circuit delay time constant $\tau = \frac{1}{R_1 C_1}$, the function block show to Figure 2.

Simulation control function block as Figure 3. Diode (D1) 1N4148 forward voltage 0.3V, R_1=820kΩ and C_1=10uF. Compare the V- and V+ that Vc control signal is high level (15V) or low level (0V) send to the switch. Control function testing waveform as Figure 4. The current 120A reduce to 80A at 1s, the mean is APG voltage 3V reduce to 2V. V+ slope slower than V- and the Vc pull high at 1S after pull low at 3.1S.

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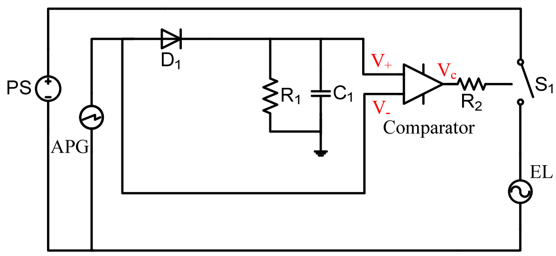

Figure 2: Control function block.

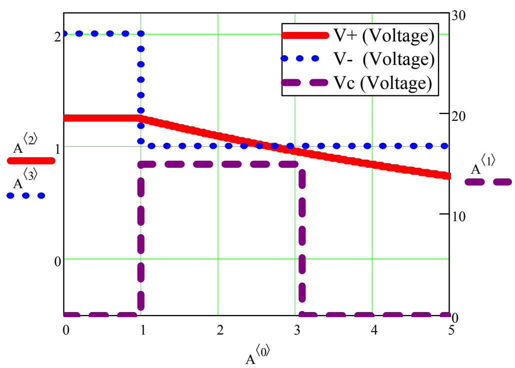

Figure 3: Control function simulation waveform.

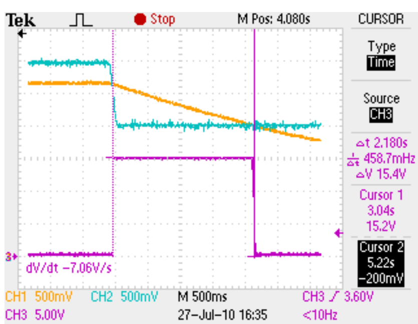

Figure 4: Control function waveform.

SIMULATION AND HARDWARE MANUFACTURE

Define all the parameter of the circuit, can be separate of the turn on and turn off mode in this circuit. Turn on and turn off mode shown as Figure 5(a)-(c). The key waveforms of the proposed discharge circuit, to one switching cycle, are shown in Figure 6.

State1[t_0~t_1]: Power supply energy stored in inductor, I_{in} current equation the I_L and D_B turn off so that the I_d=0A. V_L to approach zero voltage and $V_{in}=V_L=V_d=V_{s1}$. Freewheel diodes drain to source breakdown voltage must higher than V_L and the on state drain current must higher than 250A. In this thesis, select double parallel of the IRFK6H250, the maximum output voltage equation to $V_{L(max)}=I_{L(max)}.R_s$.

State1[t_1~t_2]: Power supply energy turn off and stored in inductor energy release to electric load. Inductor voltage reserves bias, so that relay will turn on and V_{s1}=0V. According the electric load setting value to discharge inductor energy until the current equation to electric load setting current $I_L=I_{EL}$. At this moment, $I_L=I_d+I_{EL}$, $V_{L(max)}=-I_{L(max)}.R_s$, $I_d=I_L-I_{EL}$, inductor must be to receive a invert voltage.

State1[t_2~t_3]: Inductor energy release to D1B~D6B when the Relay turn off. $I_L=I_d$ reduce the current until inductor energy release complete.

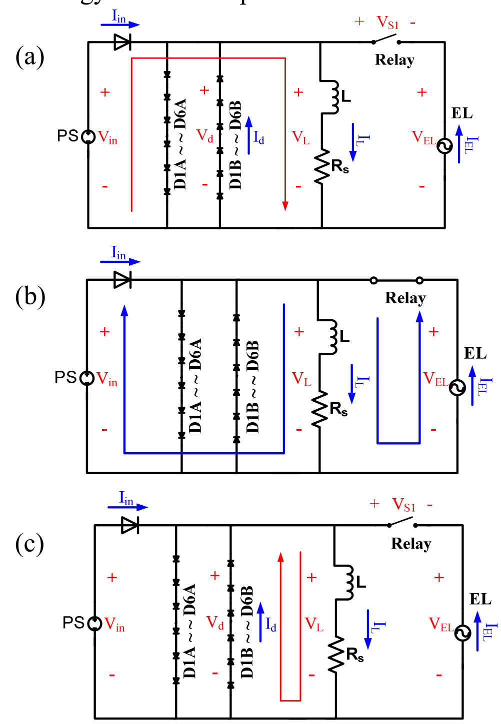

Figure 5: Circuit operation mode. (a) Inductor stored energy [t_0~t_1]; (b) Inductor release energy to electric load [t_1~t_2]; (c) Inductor release energy to protection diode [t_2~t_3].

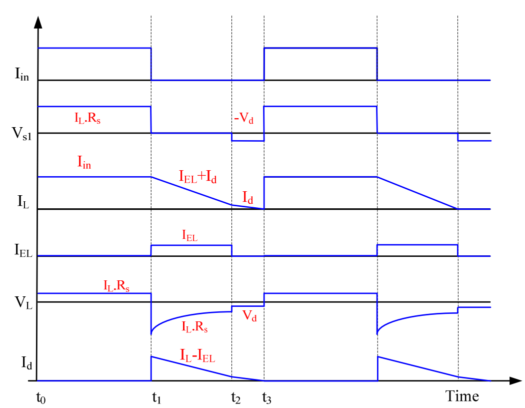

Figure 6: Theoretical waveforms of circuit.

TESTING WAVEFORM AND RESULT EXPERIMENTS

To use the Uni polar power supply provide by chroma Ldt. The 62150H-40 power supplies can provide have 225kW energy with the maximum loading. It will output current must be proven to be less than 50mA and the

Voltage ripple less than 15mV. The specifications of the power supply are listed in Table 1.

Table 1: Specifications of the 62150H-40 Power Supply

Specification	Uni-polar Power Supply
Output power energy	+375A/+600V
Line Regulation (V/I)	±0.01% / ±0.05%
Load Regulation (V/I)	±0.02% / ±0.1%
Output Noise (P-P)	60mV
Voltage Ripple (rms)	15mV
Current Ripple (rms)	50mA
Voltage Slew Rate Range	0.001V~5V/ms
Current Slew Rate Range	0.001A~1A/ms or INF

The 62150H-40 supply 310A through to superconductor leakage resistance 4.31mΩ. Setting output current is 310Ampere and output voltage is 1.337V. Figure 7 has shown as superconductor in NSRRC testing environment. The first time, supply energy to superconductor and the current rise to 310 ampere. Rising time almost has 1500 second in the charging step. Falling time has two step, (1) addition a discharge circuit and (2) Non-discharge circuit. Figure 8 has shown superconductor rising and falling output current. Addition a discharge circuit to increase superconductor release energy from 310A to 100A. Discharge time is 700 seconds and slope is 0.3A/s. Non-discharge circuit output current from 100A to 0A. Discharge time is 2500 seconds and slope is 0.04A/s.

Figure 7: Superconductor testing environment.

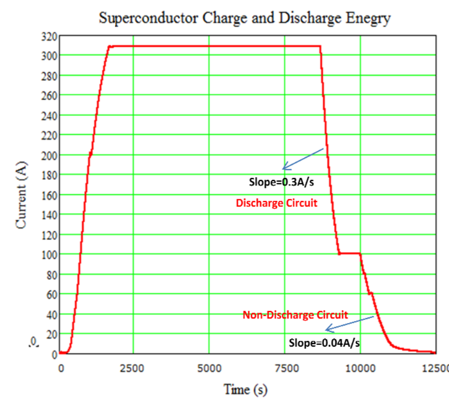

Figure 8: Superconductor rising and falling output current.

CONCLUSION

A new type Uni-polar power supply design and construction of low voltage high current with for superconductor. The test results have shown that the design of Uni-polar power supply is correct, and it has achieved the required specifications. The operation sensitivity and reliability of current reduce and the energy will dump to electric load to measure the power system safely.

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