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Modified Design of Power Supply System for 100 Tesla Pulsed Magnetic Field

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Mon-Af-Po1.12-18

Introduction

To achieve 100 Tesla pulsed magnetic field, a high energy hybrid pulsed power system consisting of pulsed generator and capacitor bank is designed to energize the three-coil magnet at the WHMFC. Because of the coupling effect between the outer coil and the middle coil, a high revers voltage on the outer coil will be induced by mutual inductance between the outer coil and the middle which cause the outer coil current drop when the middle coil is fired. Based on the analysis of the mathematical model for power supply circuit, this paper proposes a modified design for power supply system which is connecting an auxiliary power supply with the outer coil in series for the compensation of the current drop.

Power supply system

The outer coil was energized by the combined series power supply of a 100 MJ/100 MW motor-generator (MG) set with two 12-pulse power converter modules and a 1000V, 12GJ battery bank. Meanwhile, the inner coil and the middle coil are energized by a 1.6 MJ/5.12 mF capacitor bank and a 11 MJ/35.2 mF capacitor bank respectively. The diagram of the power supply is shown in Fig. 1.

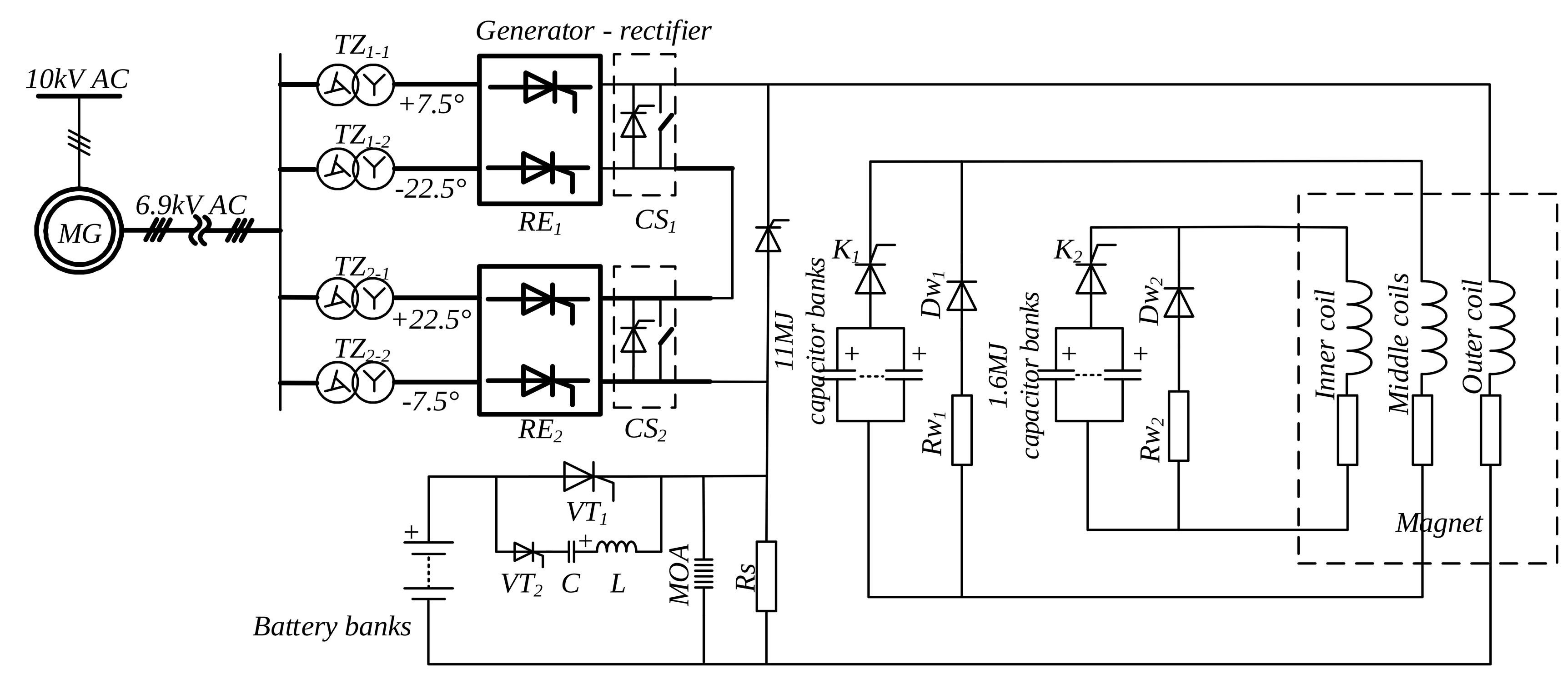

Fig. 1. The power supply schematic of the 100 T pulsed magnet

According to the designed control timing, the outer coil is fired firstly. Then the middle coil is fired by the 11 MJ capacitor bank when the background magnetic field provided by the outer coil reaches 20 T. Finally, the inner coil is fired by 1.6 MJ capacitor bank 17.5ms after the middle coil is fired.

Modification of the First 100 T Nondestructive Magnet System at WHMFC

When the current of the outer coil reach the set value ($t=t_1$), the middle coil is triggered. The voltage equation of the outer coil is:

$$u_{dc}(t) = L_{out}\left(\frac{d}{dt}i_{out}(t)\right) + i_{out}(t)R_{out} + M_1\left(\frac{d}{dt}i_{mid}(t)\right)$$

$$\Delta U_{out} = \frac{M_1}{L_{mid}L_{out} - M_1^2} \cdot [-L_{out}i_{mid}(t_1)R_{mid} + i_{out}(t_1)R_{out}M_1 + L_{out}u_{mid}(t_1) - u_{dc}(t_1)M_1]$$

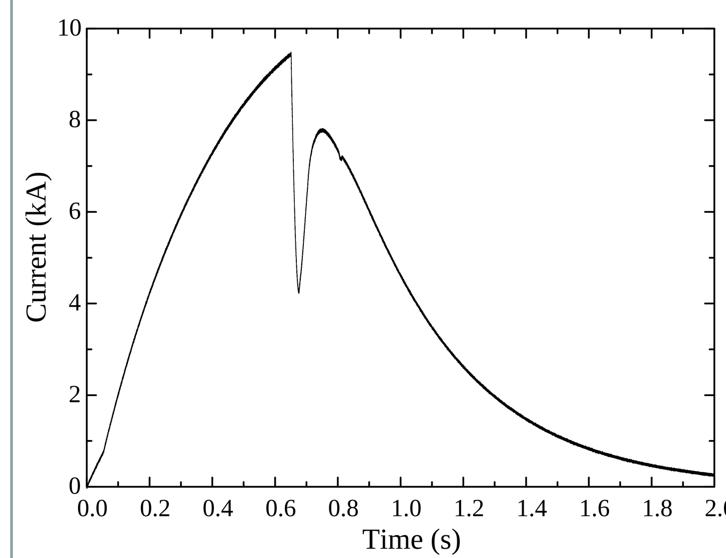

Fig. 2. The topology of the magnet power supply with an auxiliary capacitor bank

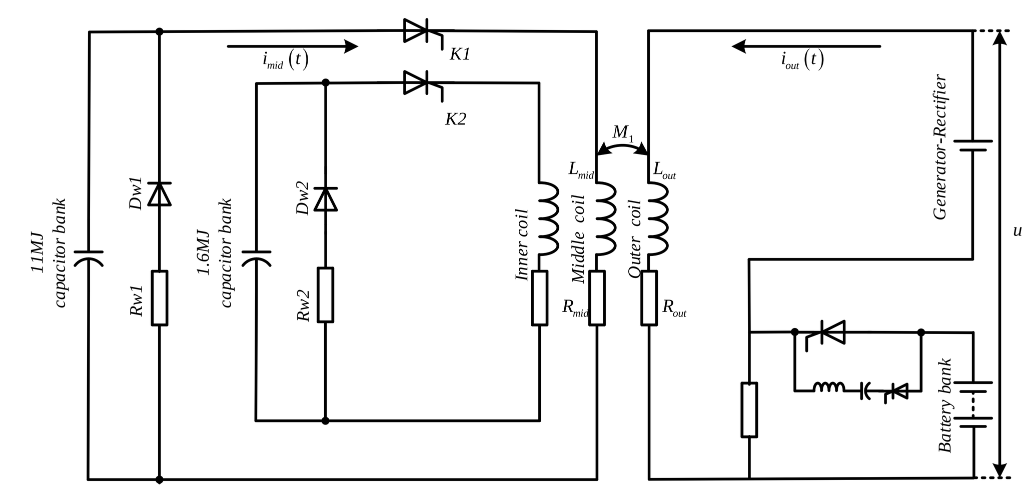

Fig. 3. The simplified model of three-coil magnet system

According to the analyses of the three-coil circuit, the di_{out}/dt of the outer coil is changed by the induced voltage which will cause current drop on outer coil. The current drop can be compensated by providing a high voltage for the outer coil to offset the induced voltage when the middle coil is fired. In this paper, an auxiliary power supply composed by capacitors is adopted to restrain the current drop in the outer coil. The scheme of circuit is shown in Fig. 4.

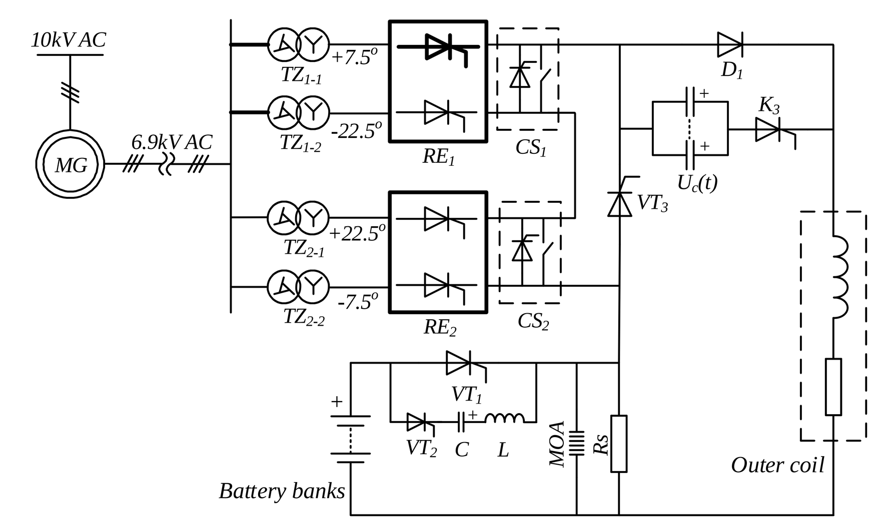

Fig. 4. The topology of the magnet power supply with an auxiliary capacitor bank

Simulation

Based on the circuit of Fig. 1 and Fig. 4, the simulation model for the power system designed in this paper is established with MATLAB/Simulink. The simulation parameters of the power supply system are set by actual parameters. Fig. 5 the outer coil has been well compensated. is the magnetic field waveform after the auxiliary capacitors bank added in the circuit. Fig. 6 shows the current of the outer coil before and after the compensation of the auxiliary capacitor bank which can prove that the current drop of the outer coil has been well compensated.

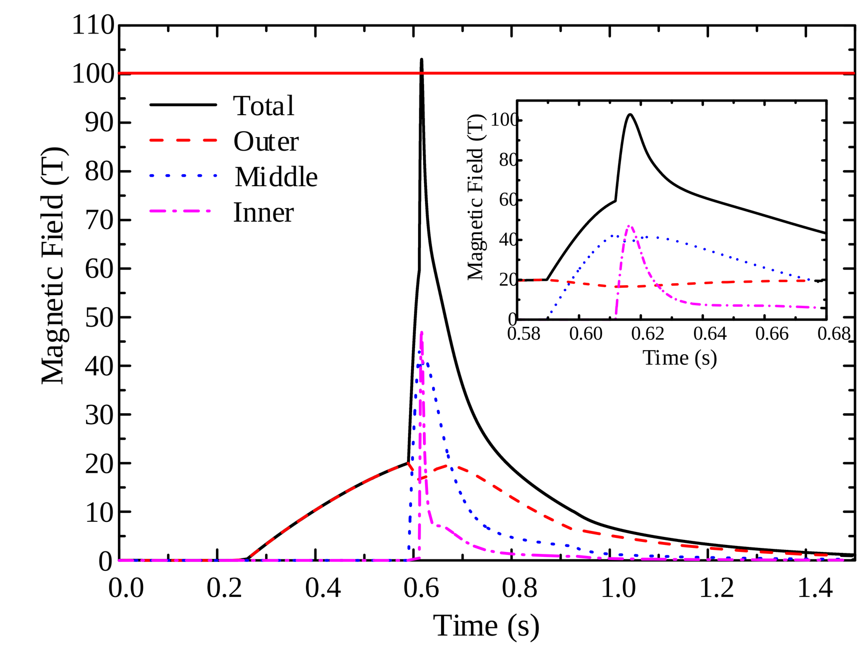

Fig. 5. The magnetic field waveform of the three-coil magnet with the auxiliary capacitor bank

The magnetic field provided by the outer coil, the middle coil and the inner coil are 16.69 T, 39.02 T and 47.3 T respectively. The platform field drop of the outer coil is compensated effectively, which has been decreased from 20 T to 16.69 T.

decreases from 20 T to 12.2 T (preliminary design)

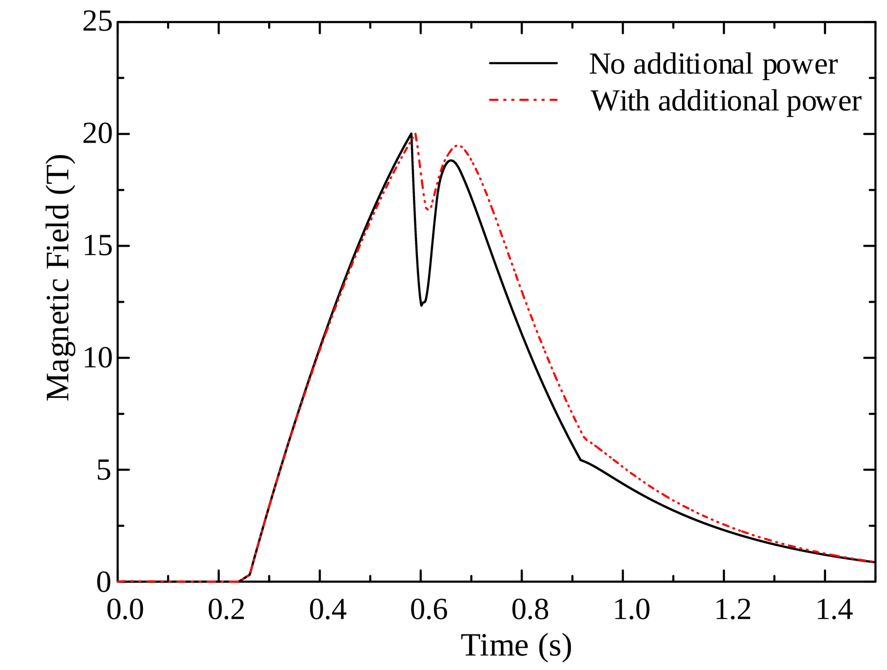

Fig. 6. The background magnetic field waveform provided by the outer coil before and after compensation

Compared with the previous circuit, the magnetic field of the outer coil is compensated by 4.49 T via the auxiliary capacitor bank. Thus, the purpose of the design is achieved and the utilization of the outer coil is improved as well.

The auxiliary capacitor bank with 44 kV initial voltage is needed to fully compensate the magnetic field drop of the outer coil. The magnetic field drop of the outer coil can be compensated by 60% under the capacitor bank of 25kV rated voltage in this paper, and the compensation effect can be further improved once larger rated voltage auxiliary capacitor bank is used.

Conclusion

- An auxiliary capacitor bank power supply is proposed to compensate the outer coil current
- The operating logic of the circuit is also investigated to ensure safe operation of the power system
- The simulation model of high power pulsed power supply sys-tem with multi-coil magnet as load is established by MATLAB/Simulink.

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PRESENTATION ID NUMBER

Mon-Af-Po1.12-18