# An Innovative Method for generating High-Stability Flat-Top Pulsed Magnetic Field

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## Abstract

In this paper, an innovative method for generating high stability flat-top pulsed magnetic field (FTPMF) based on battery power supply is proposed. The system including a bypass circuit and a divider resistor is developed. The bypass circuit is in parallel with the magnet to form a parallel branch, with which the divider resistor is in series. Different from traditional application, the IGBT in bypass circuit works in linear area, as a controllable constant current source, rather than in the switch mode. The current of bypass circuit can be adjusted by the driving voltage of IGBT to achieve the regulation of the voltage division ratio continuously between divider resistor and magnet. The current of magnet can maintain stability with feedback control, and high stability flat-top pulsed magnetic field can be obtained. In this paper, the performance of IGBT working in linear area was researched. The prototype has been developed, and the experiment was conducted, which proved that the high stability current can be achieved by this way.

## I Introduction

The high pulsed magnetic field is one of the most important tools in experimental physics for discovering uncertain phenomenon and providing higher resolution of resonance phenomena. In some scientific research, the high stability FTPMF is necessary to gain a sufficiently good signal-to-noise ratio.

In recent years, there're lots of facilities generating FTPMF have been developed. However, the duration and stability of FTPMF still to be improved.

The power supply for generating high pulsed magnetic field mainly include AC flywheel generator, capacitor-bank and lead-acid battery. In this paper, an innovative method for generating high stability FTPMF based on battery power supply is proposed. The pretest has been made to prove the feasibility of the method.

## II Method and Principle

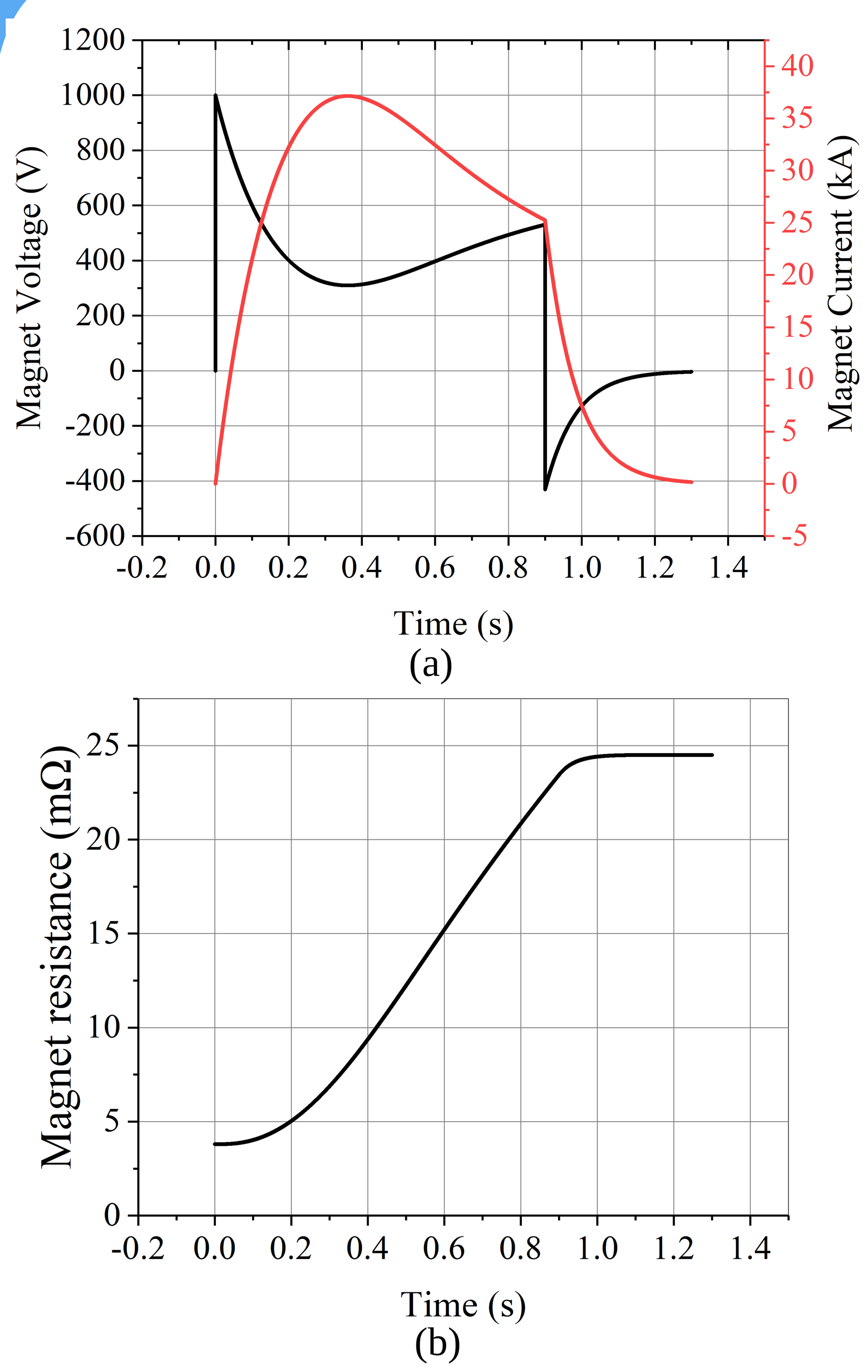


Fig.1 Experiment results of the long pulse field facility without regulation. (a) Current and voltage of the magnet. (b) Magnet resistance variation.

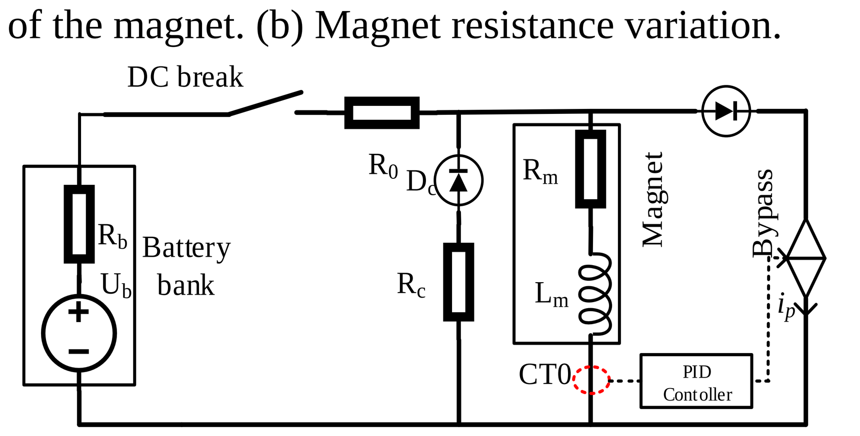


Fig.3 The principle schematic of the high stability FTPMF system. The divider resistance consists of the internal resistance of battery bank $R_b$ and resistance $R_0$ including cable resistance and extra series resistance. $D_c$ and $R_c$ is the cowbar branch. CT0 is the current sensor. The bypass is equivalent to a VCCS.

The advantage of lead-acid battery is stable output and no ripple. The reason why the magnet field can't keep flat is that the Joule's heating effect which makes the magnet resistance increase. The magnet current would decline slowly after reaching the peak without regulation. Just like Fig. 1.

When the IGBT is driven linear active region, its output current is controlled by the drive voltage. The transfer characteristic of IGBT, FF100R12RT4 (1200V /100A) is shown in Fig. 2.

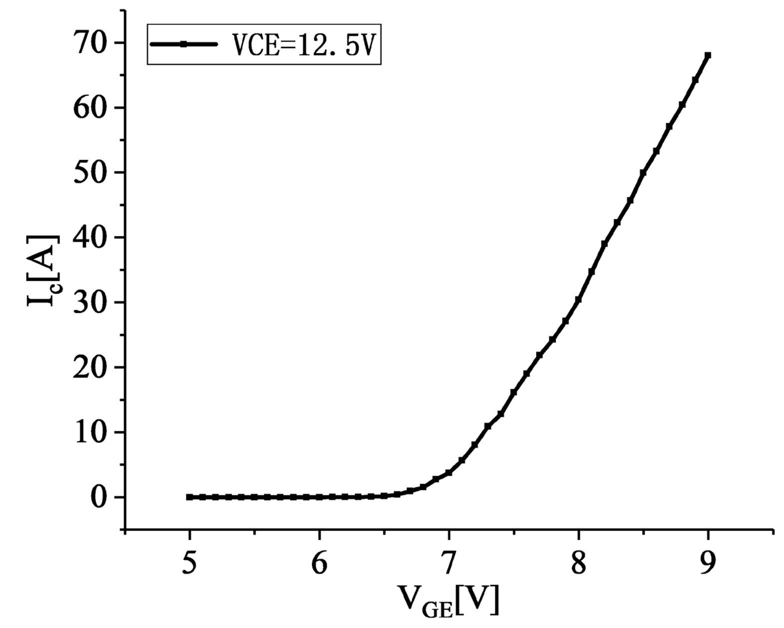


Fig.2 The experiment result of IGBT transfer characteristic.

The relationship between IGBT conducted current and gate driving voltage can be got through curve fitting.

$$I_C = 8.55V_{GE}^2 - 104.38V_{GE} + 317.23 \quad (6.5V \le V_{GE} \le 9V)$$

A new system including the bypass circuit and the divider resistor is developed to generate FTPMF. The principle schematic is shown in Fig. 3. The IGBT in bypass circuit is driven in the linear active region, working as a controllable constant current source. The voltage division ratio between divider resistor and magnet can be regulated continuously, when the IGBT current is adjusted by the driving voltage of IGBT.

## III. The Simulation of FTPMF

The simulation of the system is necessary to evaluate the value of divider resistance and the power dissipation and energy loss of bypass. The parameters and numbers of IGBT can be confirmed. To achieve 40T FTPMF, the circuit parameters are chosen, as shown in TABLE I, in the simulation.

TABLE I. Circuit Parameters for 40T

| | | |
|---|---|---|
| Battery voltage $U_b$ | | 1000V |
| Divider resistor ($R_b$+$R_0$) | | 17.55mΩ |
| Crowbar resistance $R_c$ | | 51mΩ |
| Magnet | Coil constant | 1.08T/kA |
| | Weight | 180kg |
| | Inductance $L_m$ | 3.4mH |
| | Resistance(77K) $R_m$ | 3.8mΩ |

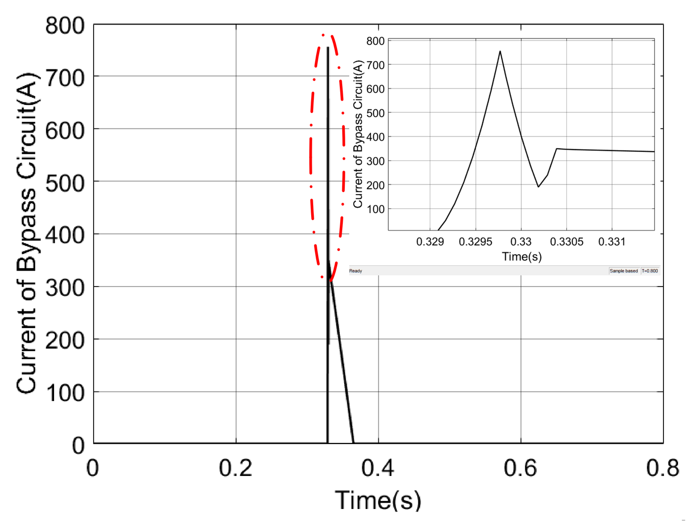


Fig.5 Current of the bypass circuit.

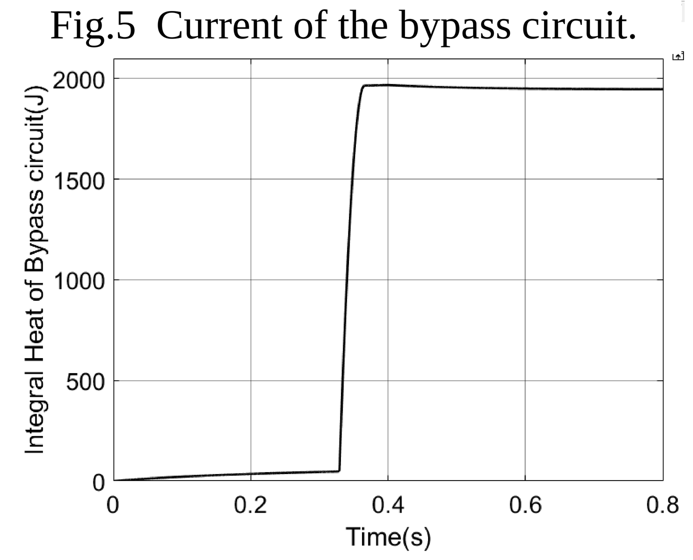


Fig.6 Integral heat of the bypass circuit.

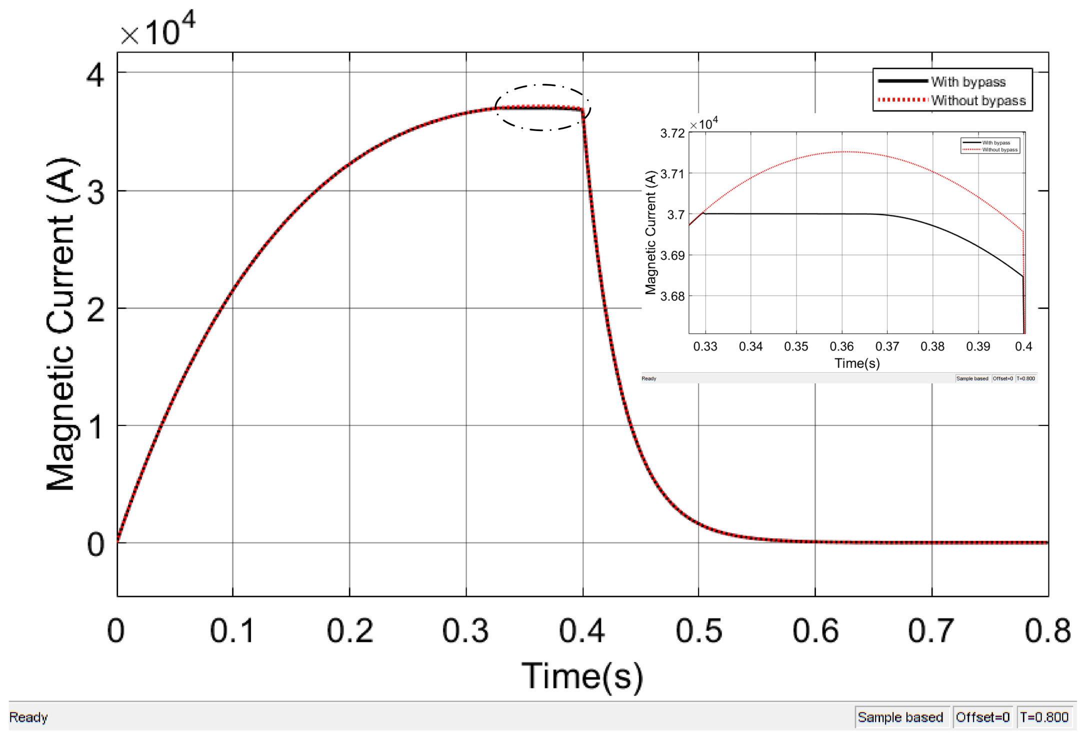


Fig.4 The simulation result of FTPMF with 39.96T/40ms.

According the simulation result, the FTPMF with 39.96T/40ms can be achieved, and the stability is about 40ppm. In practice the stability with 40ppm is almost impossible to achieve for some uncertain factors, such as electromagnetic interference and semiconductor device parameter stability. The stability with 100ppm can be achieved empirically.

According the current of bypass circuit shown in Fig. 5, about ten FF100R12RT4 (1200V /100A) are needed for 40T. The thermal performance and voltage endurance capability of the device can meet the requirement.

## IV. The experiment result and conclusion

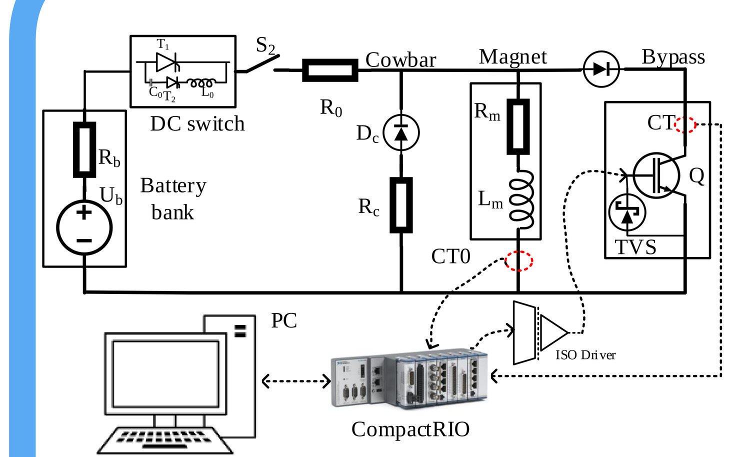


Fig.7 The prototype system of FTPMF.

TABLE II. Circuit Parameters in pretest

| | | |
|---|---|---|
| Battery voltage $U_b$ | | 25.6V |
| Internal resistance $R_b$ | | 6.6mΩ |
| Resistor in series $R_0$ | | 75mΩ |
| Crowbar resistance $R_c$ | | 1Ω |
| IGBT of bypass circuit | | FF100R12RT4 |
| Magnet | Inductance $L_m$ | 7.8mH |
| | Resistance $R_m$ | 359.06mΩ |

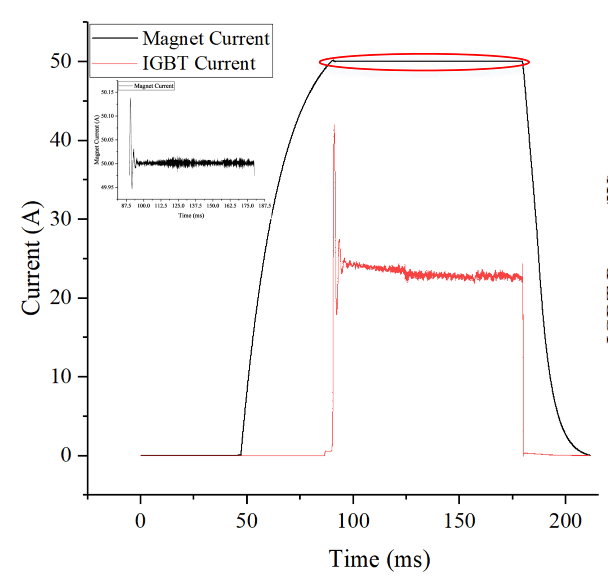


Fig.8 Experiment result of Magnet current and IGBT current.

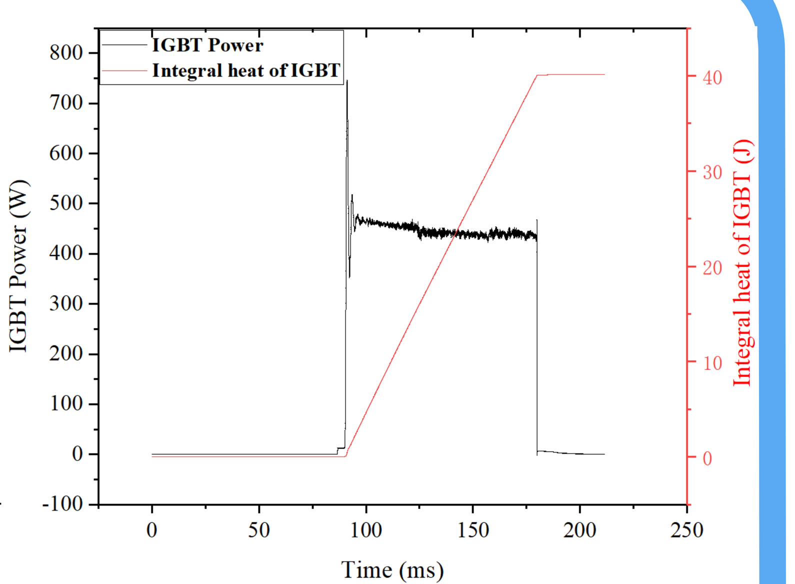


Fig.9 Experiment result of Integral heat of IGBT and IGBT Power.

- ➢ When the bypass circuit is closed, the magnet current peak is about 58A.The magnet current is 50A± 0.01A by feedback control regulation.
- ➢ There is ripple, caused by the IGBT current jitter, during the flat-top. This can be improved further.