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A Current-Injection-Based Approach for Reducing Power loss of the IGBT of Linear Bypass in the Battery-bank-Based FTPMF System

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I. Introduction

- A high stability flat-top pulse magnetic field (FTPMF) Facility based on the battery power supply with a linear bypass circuit was built in Wuhan National High Magnetic Field Center (WHMFC) in 2018. The linear bypass circuit mainly consists of the IGBTs operating in the active region and a power resistor connected in series with IGBTs. The bypass current is adjusted by the gate voltage of IGBTs to regulate the voltage of magnet continuously. With two IGBTs, FZ3600R17- KE3, the FTPMF of 23.370 T/ 100 ms/ 64.2 ppm has been achieved.
- We had planned to upgrade the facility to achieve a high stability FTPMF of 40 T. However, the terminal voltage of IGBTs is high due to operating in the active region, which limits their through-current capability. In this poster, an approach of injecting current to the power resistor is proposed to reduce the terminal voltage of IGBTs. In this way, the through-current capability of IGBT will be enhanced greatly and the regulation scope of the FTPMF system will be expanded with the same number of IGBT, and the number of IGBTs can be reduced from 35 to 4 in achieving an FTPMF of 40T.

II. Design and Simulation

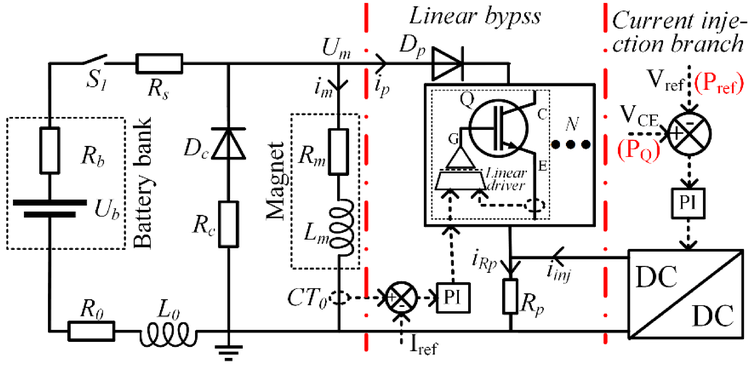

Fig. 1 Circuit schematic of system

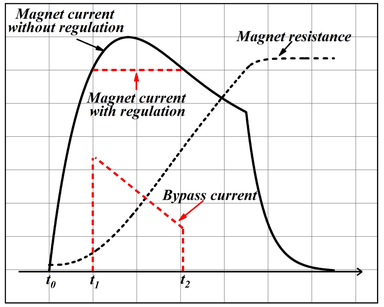

Fig. 2 Principium of the flat-top

- The system, whose circuit schematic is illustrated in Fig. 1, contains an FTPMF system[1] and a DC convert controlled by the terminal voltage of IGBT or the power of IGBT.
- The FTPMF system consists of consists of a battery-bank, a DC control switch S1[2], a protection breaker, a crowbar branch, a pulsed magnet, and a linear bypass.
- Although the output voltage of battery-bank is stable, the Joule effect increases the magnet resistance slowly. Therefore, the magnetic field cannot remain constant without regulation of the linear bypass. Show in Fig. 2.
- The terminal voltage of IGBTs is high due to operating in the active region(show in Fig. 3[3]), which limits their through-current capability.
- The only way to repress the power loss of IGBT located in bypass is to reduce its terminal voltage, because its current is used as the variable regulating the magnet current.
- In order to adjust the terminal voltage of IGBT, a method of current injection to the bypass resistor Rp is proposed, as shown in Fig. 1. By this way, the terminal voltage of IGBTs is reduced, and thus the power loss is transferred from IGBTs to the bypass resistor Rp. The resistor is cheap and indefectible, therefore it is beneficial to safety and cost of the system.

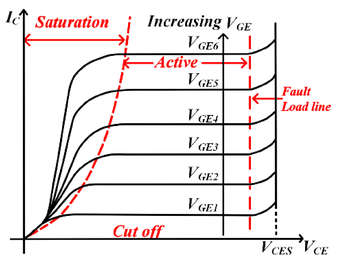

Fig. 3 Output characteristics of IGBT

III. Result and Discussion

Circuit parameters	Cable resistance R_0		8 mΩ
	Cable inductance L_0		40 μH
	Series resistor R_s		5 mΩ
	Bypass resistor R_p		55 mΩ
	Crowbar resistor R_c		10 mΩ
	Bypass IGBTs		FZ3600R17KE3-B2
	Diodes		DZ3600S17K3
Battery bank	Output voltage U_b		1200 V
	Internal resistance R_b		16.5 mΩ
Magnet	Inductance L_m		8 mH
	Resistance R_m		6.2 mΩ (77K)
	Coil constant		1.4 T/kA
	Weight M		170 kg
DC converter	Input voltage		800 V
	Output LC filter	inductance	0.5 mH
		capacitance	10 uF

Table I SPECIFICATIONS OF SYSTEM SIMULATION

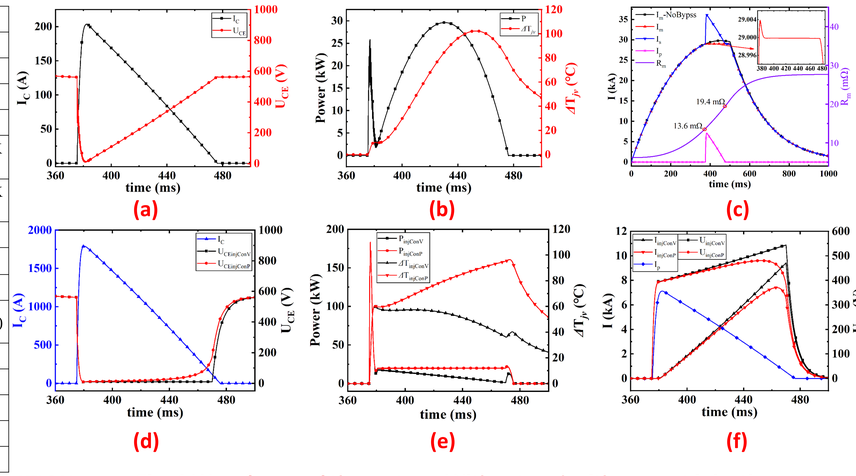

Fig. 4 Waveforms of the system. Without and with current injection

- Fig. 4(a), (b) is the waveforms of each IGBT without current injection and with 35 IGBTs in parallel, in achieving 40T/100ms FTPMF. And (c) is the battery-bank current (Is), magnet current (Im), bypass current (Ip), and magnet resistance (Rm), which will not change with or without current injection. (d), (e) is the comparison of (a), (b), respectively, when the number of IGBTs is reduced from 35 to 4 but the current injection is working. (f) is the waveforms in DC converter.
- power loss of the IGBT of linear bypass in the battery-bank-based FTPMF System can be reduced by 88%. So the number of IGBTs can be reduced from 35 to 4 in achieving an FTPMF of 40T.

IV. Conclusion

- The number of IGBTs of linear bypass in the 40 T/ 100 ms high stability (about 50ppm) battery-bank-based FTPMF System can be reduced from 35 to 4, makes it possible and Cost-effective. It is meaningful for many scientific experiments.
- The experiment of 10 A has been implemented to verify the feasibility of the principle, and it will take some time to com-plete the expansion of battery-bank and development of DC converter to achieve the expected goal.
- Now an insufficient compensation method for DC converter is under discussion, in which the terminal voltage of IGBT can not be compensate to reference voltage(5V) when the current of bypass is low. This method can simplify the achievement of DC converter but slightly increase the power consumption.

References

1. S. Zhang, Z. Wang, et al. IEEE Transactions on Power Electronics, 2019.
2. T. Ding, J. Wang, et al. IEEE Transactions on Applied Superconductivity, 22, 5400404, 2012.
3. J. Lutz, H. Schlangenotto, et al. Springer Science & Business Media, 2011.