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The Influence of SMES Magnet Operation Parameters on Voltage Distribution Characteristic

Jing Shi[a], Dengquan Lin[a], Meng Liao[a], Wangwang Yang[a], Zitong Zhang[a], Ying Xu[a], Li Ren[a]

[a] *Huazhong University of Science and Technology, Wuhan 430074, China*

Abstract——The voltage distribution on the magnet of superconducting Magnetic Energy Storage (SMES) system are the result of the combined effect of system power demand, operation control of power condition system (PCS) and magnet parameters, which is a key issue that influence the stability and security of SMES magnet. This paper mainly focuses on the interaction between the different components and the influence factors on voltage distribution on the magnet. Firstly, the hybrid model which integrate the power system dynamics, the detailed device of PCS and the transient model of magnet is built. Then, from the perspective of power requirement of power system, operation mode and control strategy of PCS, the voltage distribution characteristics are comprehensively analyzed. Finally, the optimization design method of operation mode to reduce the unevenness of voltage distribution is proposed.

Index Terms——SMES magnet, Voltage Source Converter, two quadrant DC/DC chopper, Voltage distribution, Power compensation.

1. Hybrid model of SMES system

The voltage distribution on the magnet of SMES system are the result of: system power demand, operation control of PCS and magnet parameters.

system-level model ⇒ operation characteristic of power grid

device-level model ⇒ detailed dynamic process of the PCS and the magnet

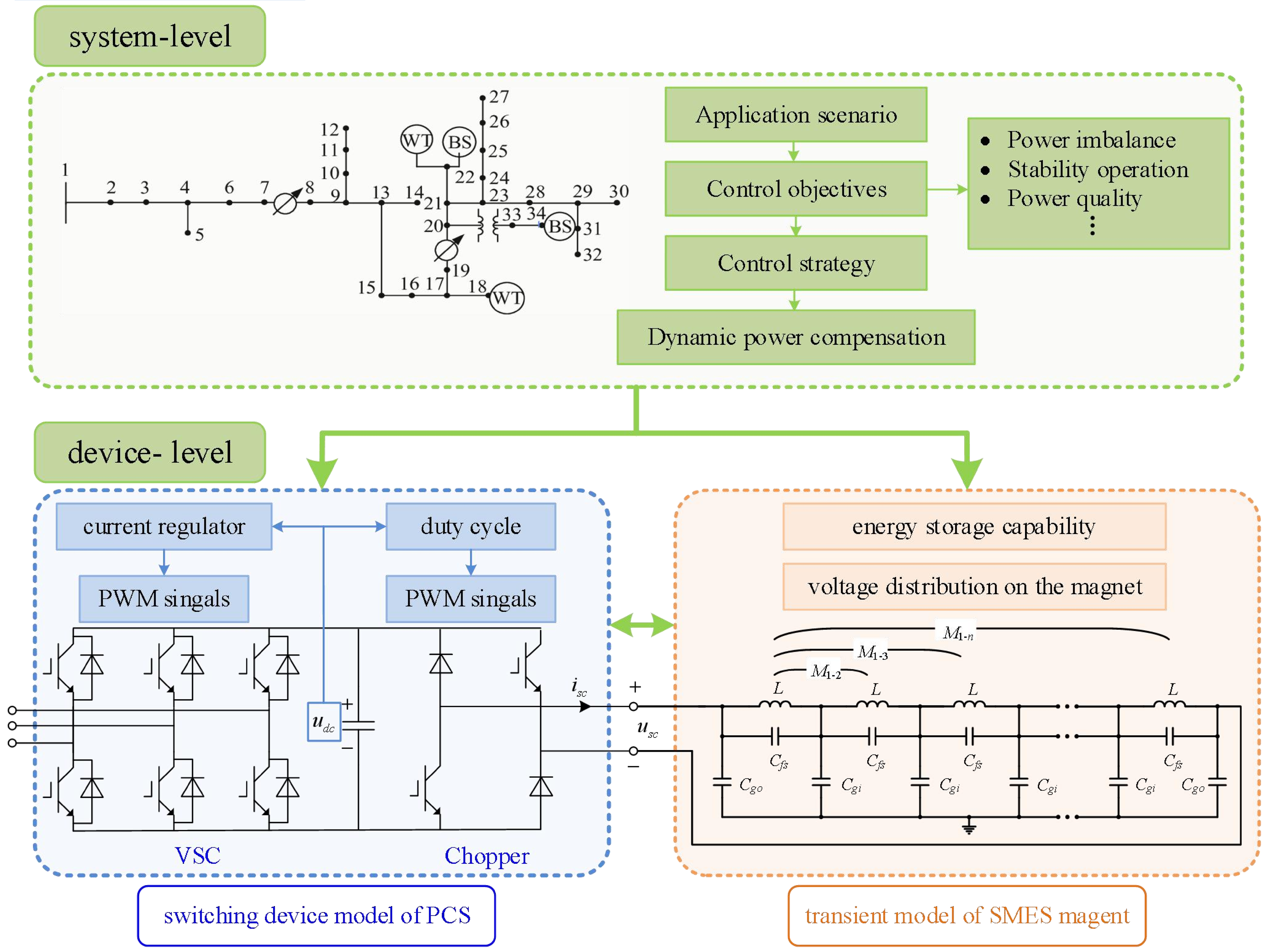

Fig.1. Schematic diagram of SMES hybrid model

A solenoid magnet and a toroidal magnet are selected for voltage distribution analysis:

TABLE I Specifications of the magnet

item	Solenoid magnet	Toroidal magnet
Tape Width (mm)	4.2	12
Tape Thickness (mm)	0.23	0.1
Distance between pancakes (mm)	0.1	0.1
Distance between turns (mm)	0.1	0.1
Insulation thickness between pancakes(mm)	2.0	/
Inner diameter of the magnet - d_t (mm)	/	260
Inner diameter of the pancake - d_i (mm)	50	150
Outer diameter of the pancake - d_o (mm)	116	270
Number of turns in one single pancake - N	100	300
Number of double pancakes - N_{DP}	10	30

2. The operation mode of DC/DC chopper

The DC/DC chopper is adopted to realize the power transfer with AC system. Its typology and switching modes will affect the voltage distribution on the magnet.

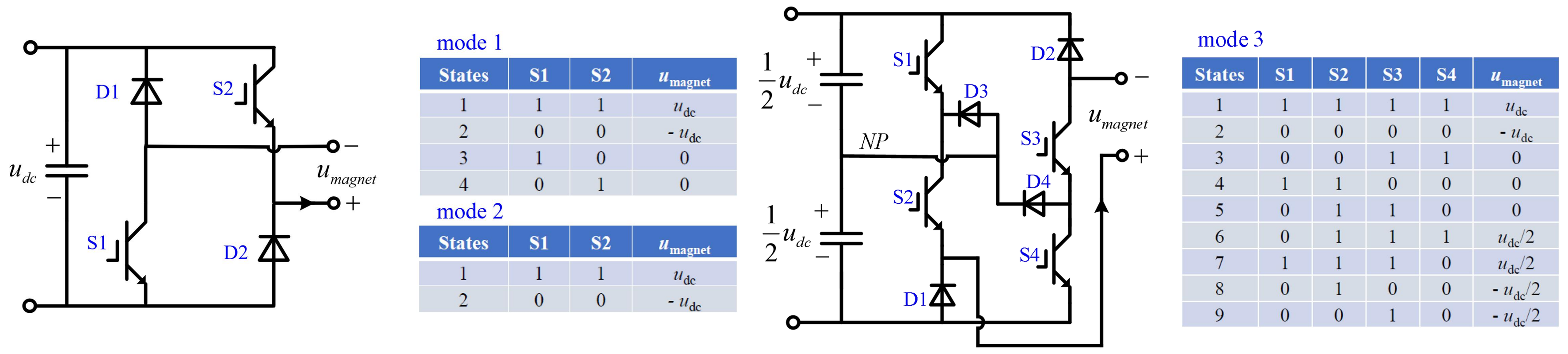

Fig.2. The typologies and switching modes of DC/DC chopper

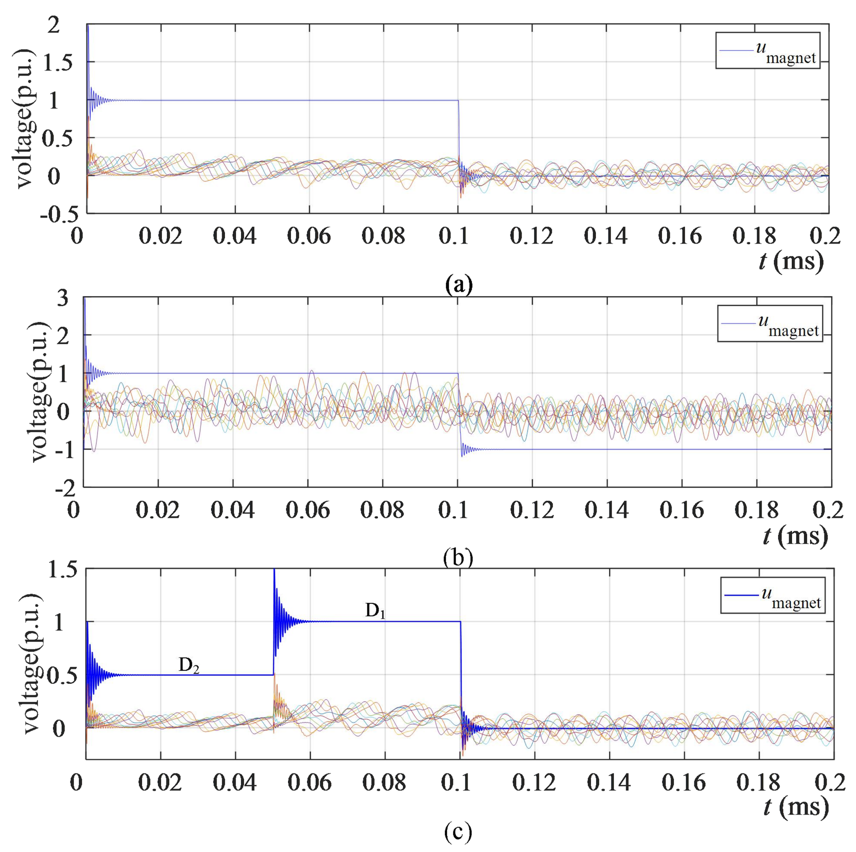

Fig.3. Voltage distribution for the solenoid magnet. (a) mode 1 (b) mode 2 (c) mode 3

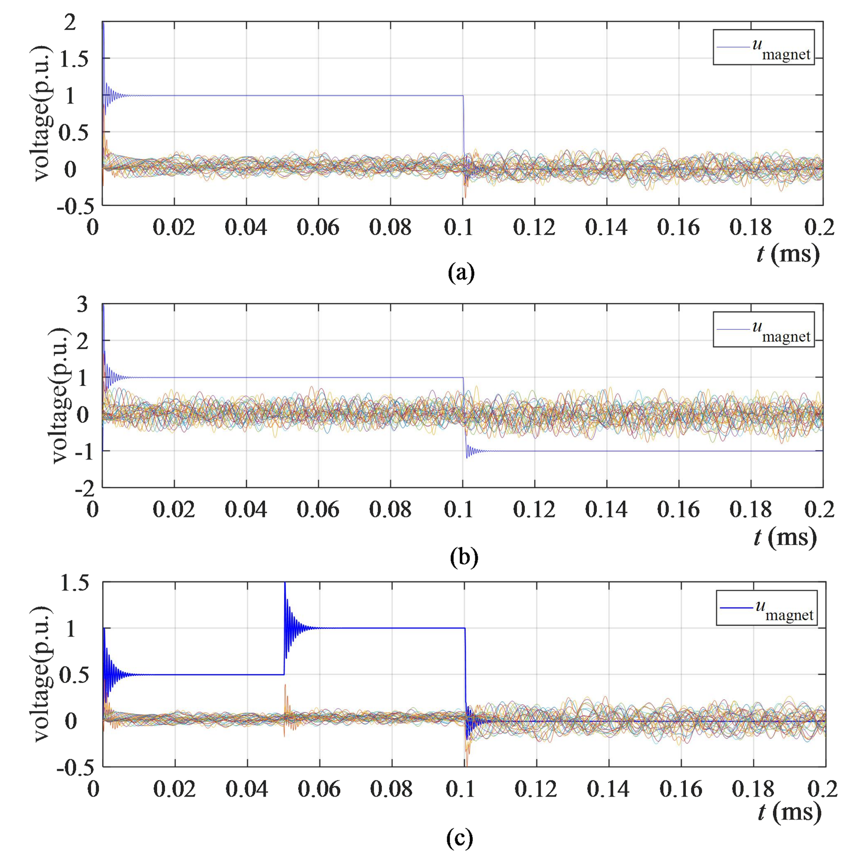

Fig.5. Voltage distribution for the toroidal magnet. (a) mode 1 (b) mode 2 (c) mode 3

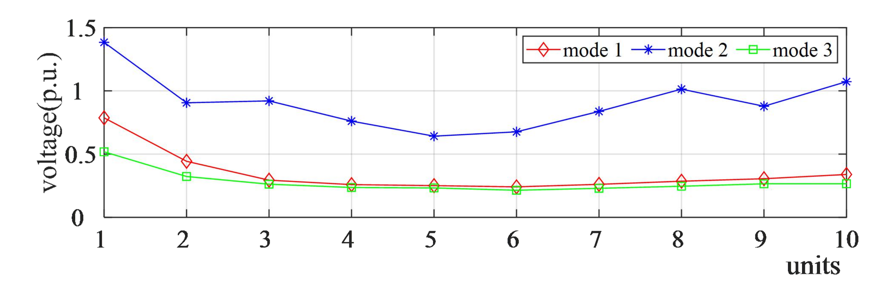

Fig.4. The maximum voltage on the double-pancakes of the solenoid magnet in different operation modes

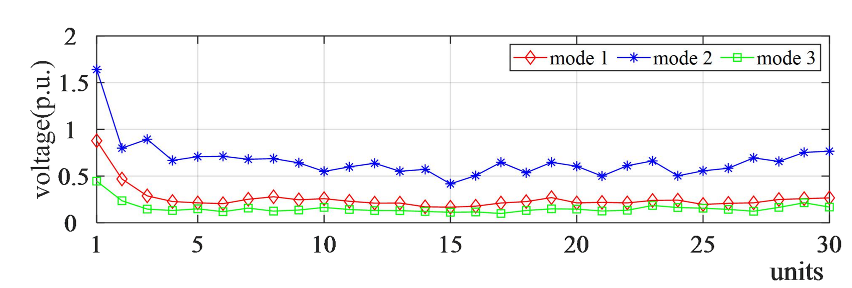

Fig.6. The maximum voltage on the double-pancakes of the toroidal magnet in different operation modes

3. The dynamic power compensation requirement

The DC side bus voltage of VSC (u_{dc}) will produce a transient fluctuation in the initial stage of the power command change, which will affect the voltage distribution on the magnet.

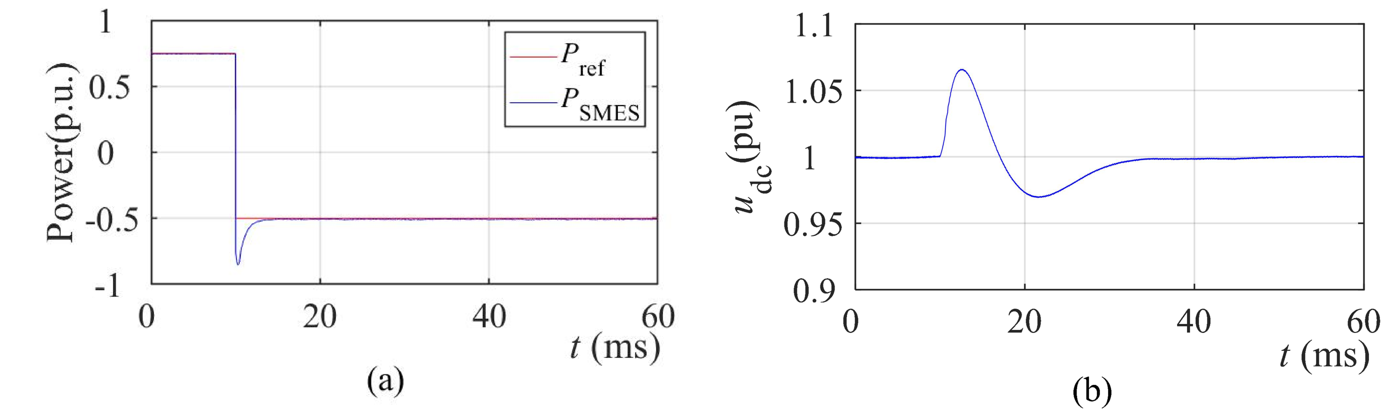

Fig.7. Power response of the SMES system. (a) SMES power (b) DC side bus voltage of VSC

the change rate of the maximum voltage on the magnet units:

$$\Delta u_{magnet} = \frac{u_{\max} - u_{base}}{u_{base}} \times 100\%$$

(a):assuming the amplitude rise rate of 0.04pu/ms;
(b):assuming the amplitude fluctuation of 0.2pu

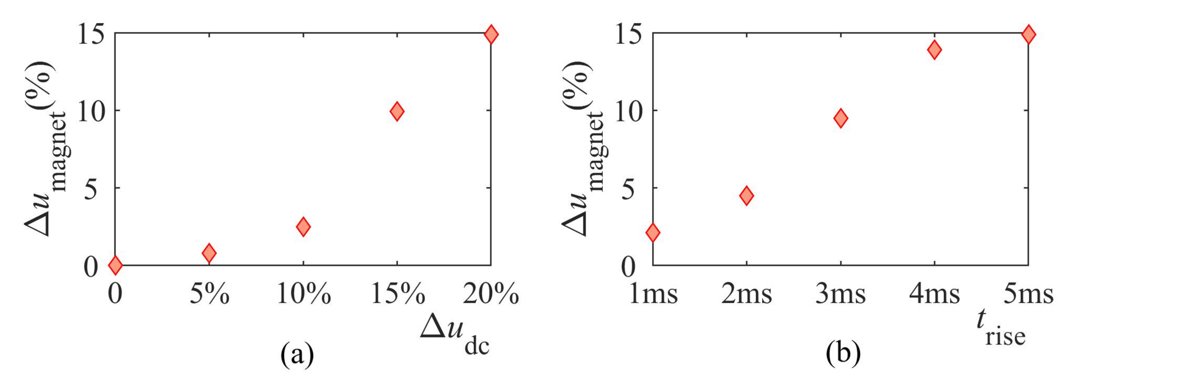

Fig.8. The influence of u_{dc} on voltage distribution of the solenoid magnet

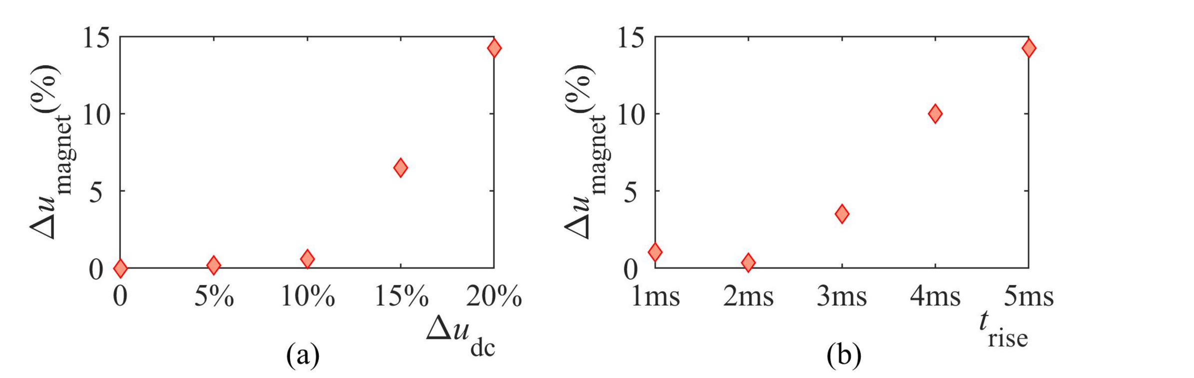

Fig.9. The influence of u_{dc} on voltage distribution of the toroidal magnet

4. CONCLUSION

This paper proposes the optimization design method of operation mode to reduce the unevenness of voltage distribution. Based on the hybrid model which integrate the power system dynamics, the detailed device of PCS and the transient model of magnet, the voltage distribution of different operation scenario is analyzed. And the switching mode of the DC/DC chopper and the transient response characteristics of the control system can be optimal designed.

1) The voltage amplitude of mode 3 is lower than that of mode 2 and mode 1, which can be concluded that the number of levels is inversely proportional to the amplitude of the overvolt-age on the magnet. However, the price of adding a level is to add four power electronic switching devices.
2) If the change rate of the maximum voltage of the magnet is to be controlled within 5%: for solenoid magnet, the rise time of u_{dc} fluctuation is required to be within 2s, and the amplitude fluctuation is within 10%; for toroidal magnet, the rise time is required to be within 3s, and the amplitude fluctuation is within 10%.

* Corresponding author: Dengquan Lin. *E-mail address:* m202171983@hust.edu.cn