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1. Introduction

For the three-stage synchronous starter/generator (TSSG), the full-bridge uncontrolled rectifier is adopted instead of half-bridge uncontrolled reciter to improve the output current capability of the main exciter (ME). Generally, when using half-bridge rectifier, the pole numbers for the main generator (MG) and ME must not be equal or integral multiple of each other to reduce current shock to the excitation system when the MG's armature winding is short-circuited. The constraint on pole ratio whether or not applies when using full-bridge rectifier is unknown.

Four MEs with different poles, as shown in Table 1, have

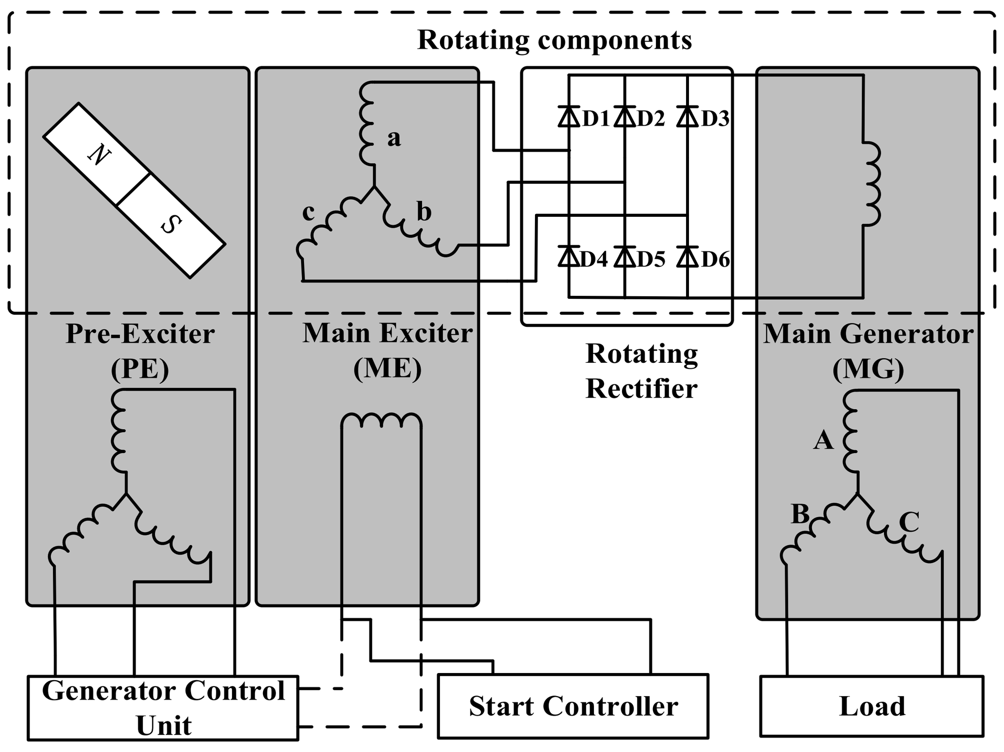


Fig. 1 Structure of the TSSG

been designed with the same outline dimension to analyze the excitation system's transient performance.

In order to maximize validity of the analysis, the four MEs are designed to supply the MG with about 25A field current, at 8000rpm with 12A field current.

Tab. 1 Poles of the MG and the ME

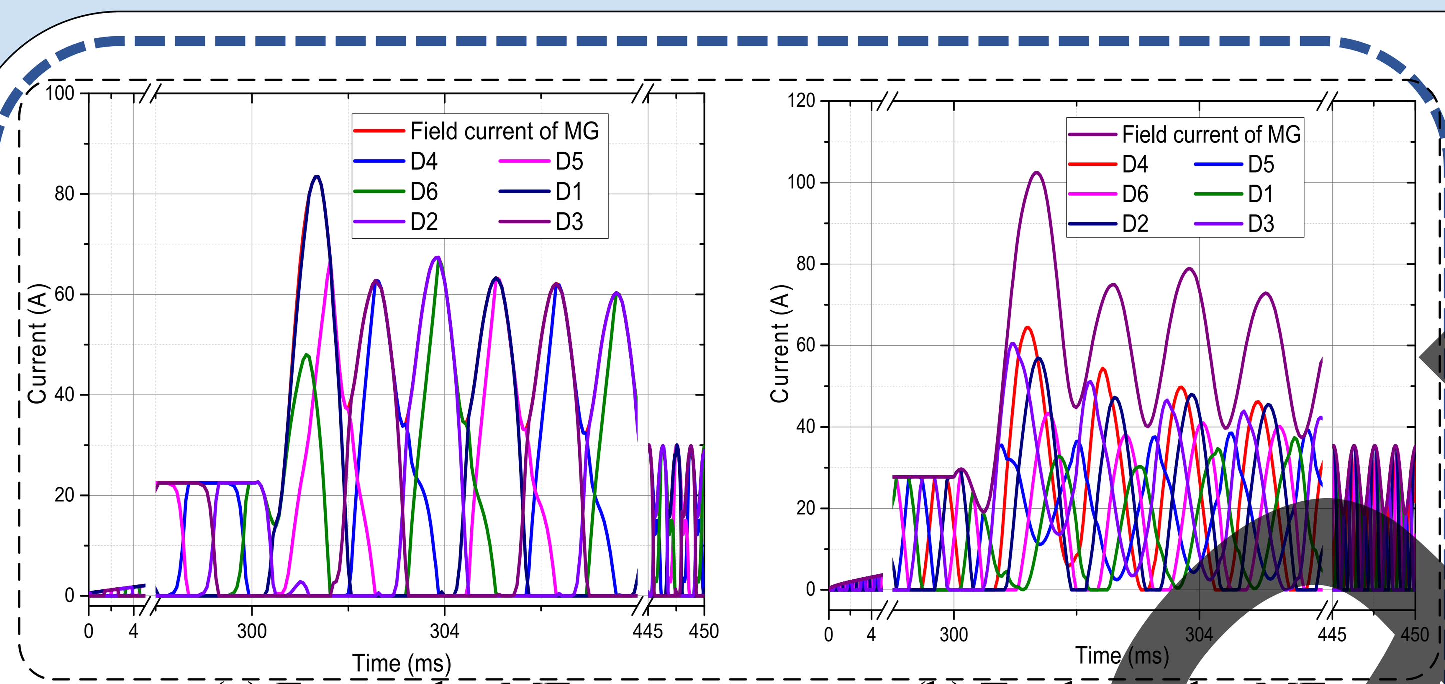
Poles of MG	Poles of ME	Pole ratio
6	2	3
6	4	1.5
6	6	1
6	12	0.5

2. Pole Ratio Influence

Currents of the MG's Field Winding and Diodes : The increased armature winding current imposes strong demagnetizing effect on excitation magnetic field which results in a sharp increase of the field current of the MG, and the maximum rates of change are all around 269%. (Fig. 2)

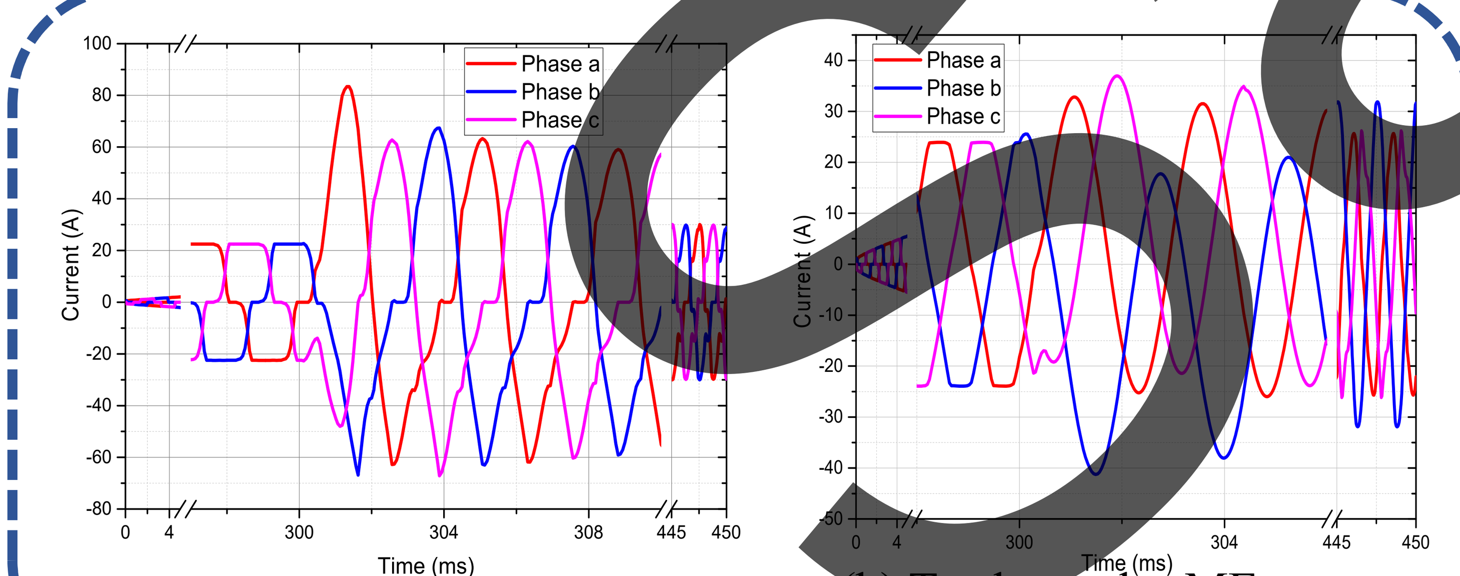
As shown in Fig. 2(b), three or two diodes located in upper or lower legs share the field surge current, fully reducing current shock to the rectifier. Fig. 2(a) indicates that certain diode itself shares the surge current which is unwanted.

Armature current of the ME: When the maximum rate occurs, equivalently six diodes absorb the field surge current. Still, for the four-poles ME, only one diode current conducts the field surge current with which the phase armature winding connected conducts the surge current directly. In other word, the constraint on pole ratio is inapplicable.



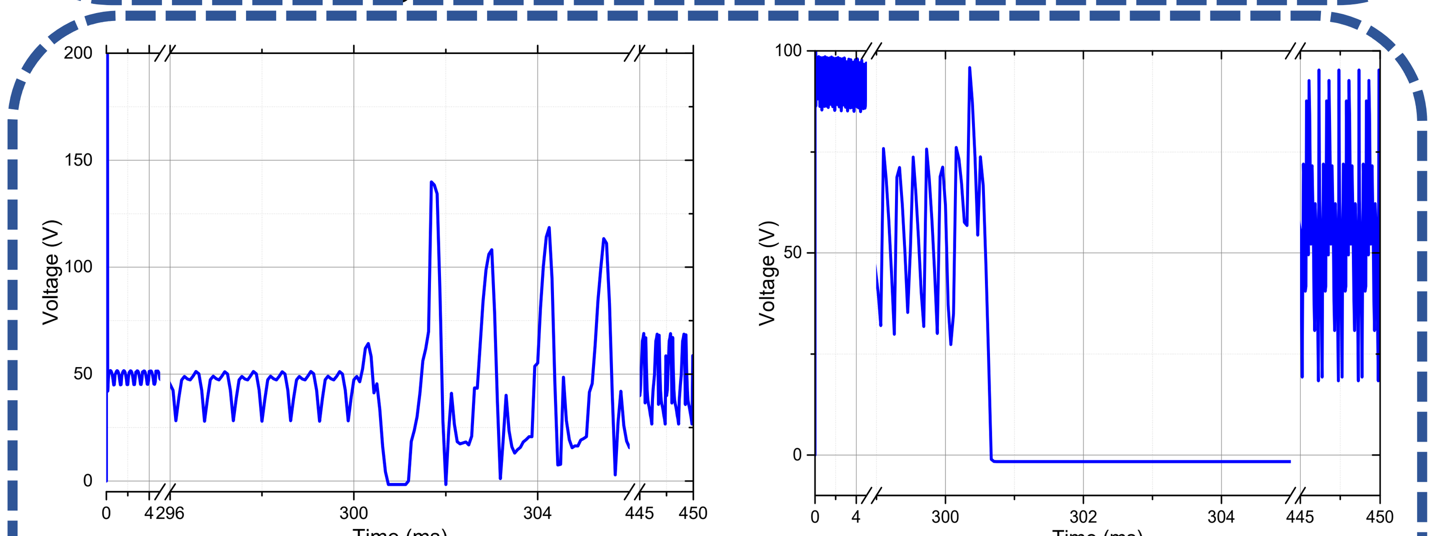
(a) Four-poles ME (b) Twelve-poles ME

Fig. 2 Diode currents and field current of the MG



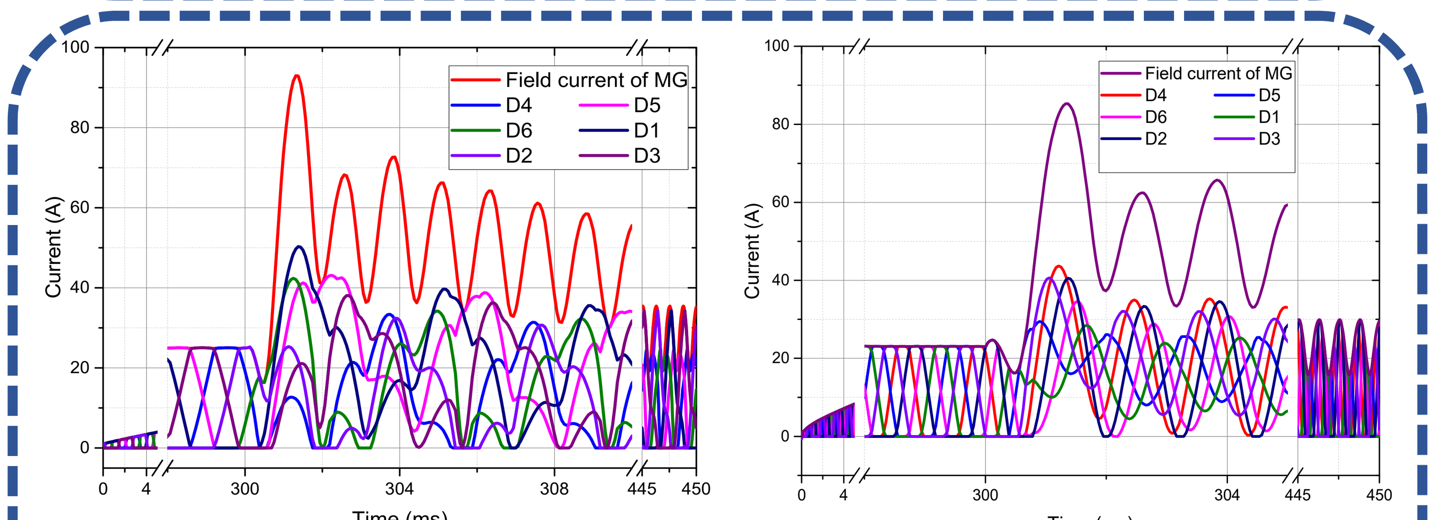
(a) Four-poles ME (b) Twelve-poles ME

Fig. 3 Armature currents of the ME



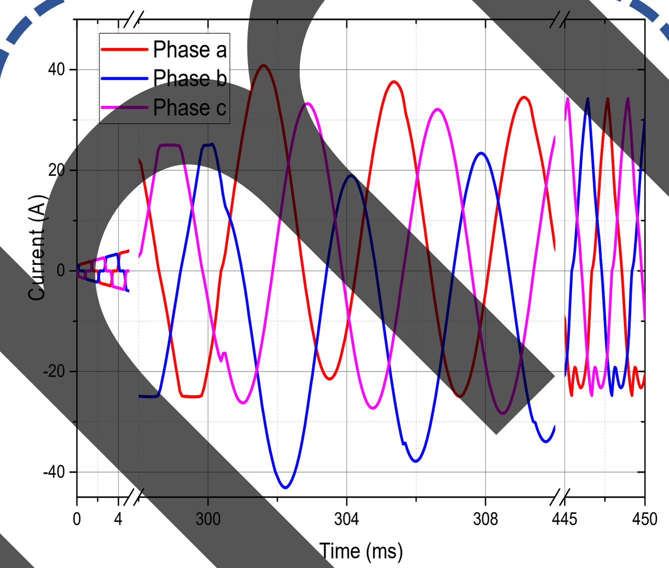
(a) Four-poles ME (b) Twelve-poles ME

Fig. 4 Terminal voltage of MG's field winding with different MEs

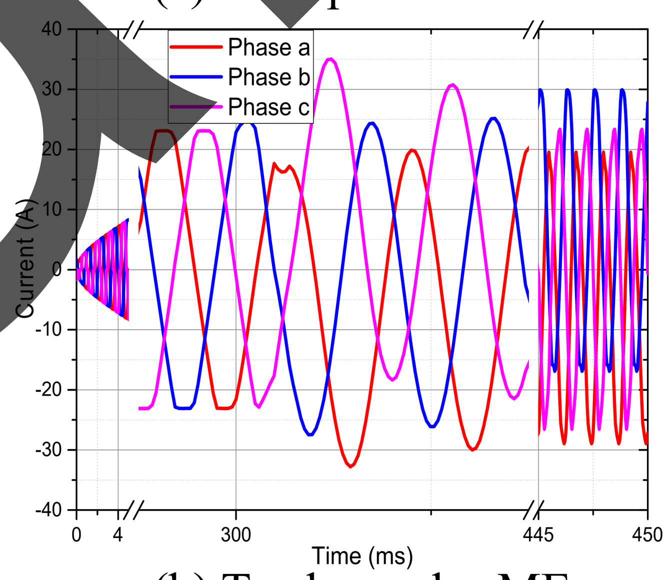


(a) Four-poles ME (b) Twelve-poles ME

Fig. 5 Diode currents and field current of MG with redesigned MEs

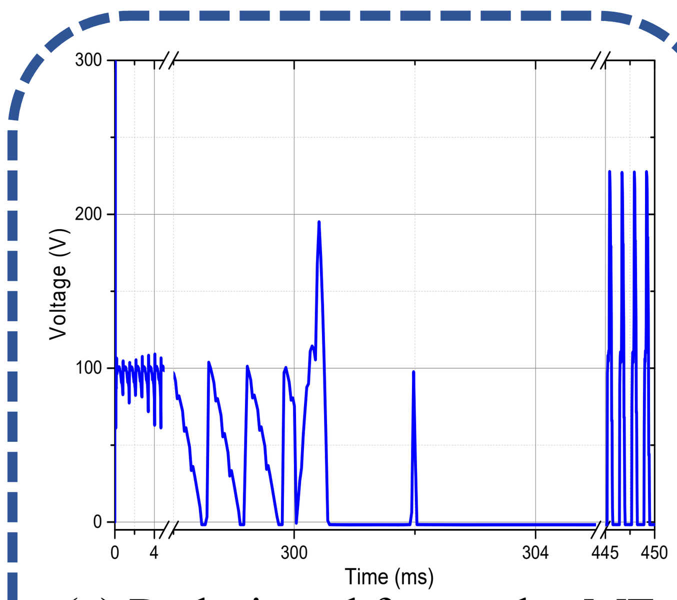


(a) Four-poles ME

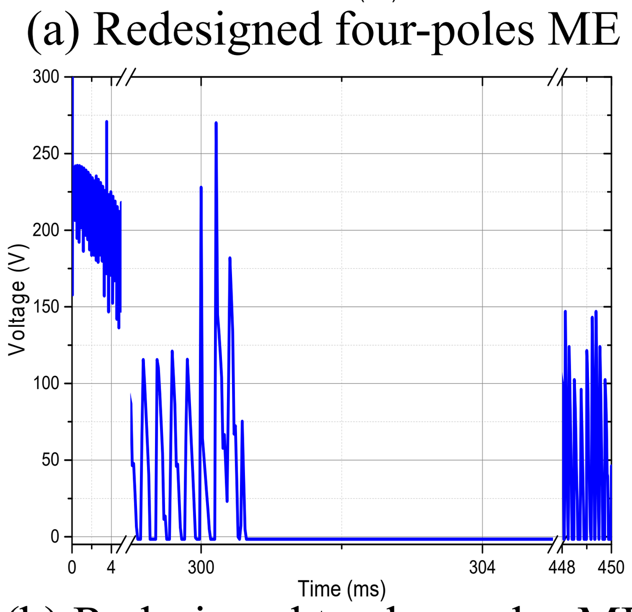


(b) Twelve-poles ME

Fig . 6 Armature currents of the redesigned MEs



(a) Redesigned four-poles ME



(b) Redesigned twelve-poles ME

Fig. 7 Terminal voltage of MG's field winding

3. Influence of Operation Mode of the Rectifier

When the rectifier operates at mode 2 or 3, shortly after the short-circuit of the MG, a constant short-circuit is imposed on the ME and there's a long period for four diodes conducting, which can be called as operation mode 4.

For the rectifier working with the 4-poles ME, it operates at mode 1 and the surge current cannot change its operation mode, which brings the excitation system with severe current shock. The rectifiers of the other three excitation systems operate at mode 3, mode 3 and mode 2 respectively. (Fig. 3-4)

One assumption is set forth that the operation mode of rectifier matters much more than the pole ratio. To prove this assumption, the 4-poles ME and 12-poles ME have been redesigned to make the rectifiers operate at mode 3 (Fig. 6-7)

Simulation results show that it's better to design the TSSG to make the rectifier work at mode 2 or 3.

Tab. 2 Maximum rates of change for currents

Exciter	Rate of change of MG current (%)		Rate of change of ME current (%)	
	Armature	Field	Diode	Armature
2 poles	145.7	269.8	74.6	44.9
4 poles	146.6	270.8	270.8	270.8
6 poles	144.1	267.8	108.2	74.2
12 poles	145.5	269.3	132.3	130.0

Tab. 3 Maximum current rates of change for the excitation system

Exciter		Diodes (%)	Armature (%)
4-poles	original	270.8	270.8
	redesigned	100.8	72.1
12-poles	original	132.3	130.0
	redesigned	89.2	51.8

4. Conclusion

For TSSG, when adopting the three-phase full-bridge rectifier, the constraint of pole ratio is no longer applicable.

In order to reduce the current shock to the excitation system when the MG's armature winding is short-circuited, one should design the TSSG to make the rectifier operate at mode 2 or 3 on the basis of ensuring the excitation system's output current capability.

Acknowledgment

This work was supported by National Natural Science Foundation of China (xxxx).

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