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Simulation Studies of a Ship Power System with SMES in Enhancing Voltage Stability

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Abstract **—During the operation of naval ships, frequent load fluctuations may lead to voltage and frequency fluctuations of the grid, which contributes to instability of the power system and decreased fuel efficiency of diesel generators. The capacity of some loads like thrusters can be comparable to that of a single generator, and their start-up or unloading will have a significant impact on the dynamic characteristics of the system. Energy storage systems provide viable solutions for improving the system's reliability and efficiency. This paper presents the analysis of the startup of a high-capacity induction motor in a simplified electric ship power system. Superconducting magnetic energy storage (SMES), which has a very fast time response, is used as energy storage module. A comparison study on two situations, with and without SMES, has been carried out in Matlab/Simulink. The results show the effectiveness of SMES in maintaining the stability of the ship power system.**

I. A Simplified Electric Ship Power System

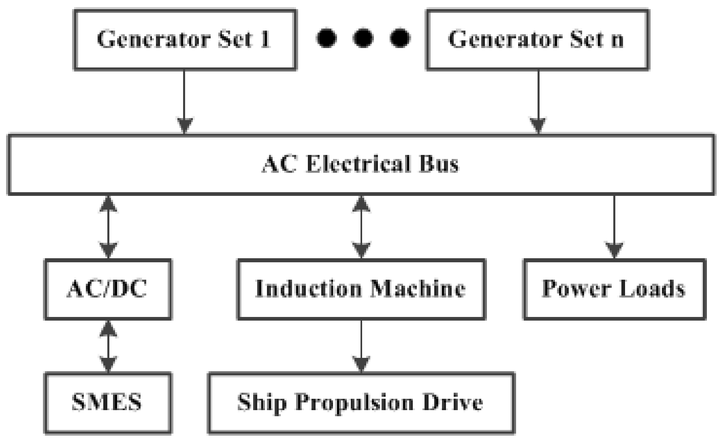
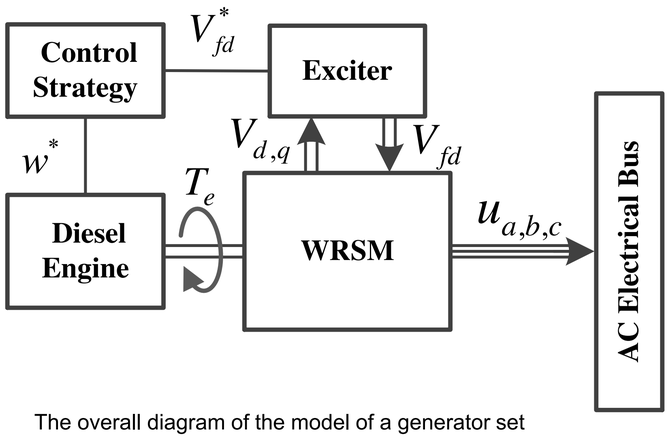


Figure 1 Naval ship electrical architecture

The architecture of a simplified electric ship power system used in this paper is shown in Fig. 1. The ship power system generally consists of two to four generator sets including an emergency one, various kinds of induction machines, power loads and SMES connected to an AC electrical bus with a DC/AC bi-directional power converter.

II. The Modeling of Each Part

➢ ***Generator Set***



The overall diagram of the model of a generator set

The governor of the diesel engine adopts PID control to ensure that the speed holds steady. The instantaneous speed of the diesel engine is compared with the specified speed and the rotor of wound rotor synchronous machine (WRSM) is driven in the form of torque. The governor can automatically adjust the oil supply according to the change of the load to make the instantaneous speed well follow the desired speed so that the grid frequency is stable.

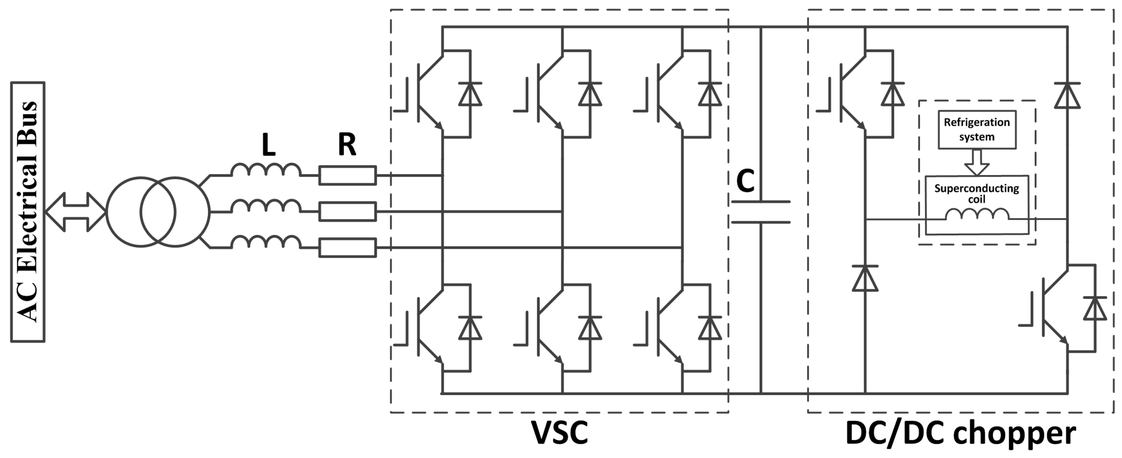
The excitation system block regulating the terminal voltage of WRSM in generating mode is a DC exciter without the exciter's saturation function. The excitation voltage of the exciter and WRSM terminal voltage changes correspondingly.

➢ ***Propulsion Loads and Other Power Loads***

The scenario of start-up of propulsion loads that can be comparable to a single generator with the capacity is simulated in the paper.

Other power loads including general lighting, computers, control panels and living electric equipments simply equalized as a static load.

➢ ***Superconducting Magnetic Energy Storage (SMES) System***



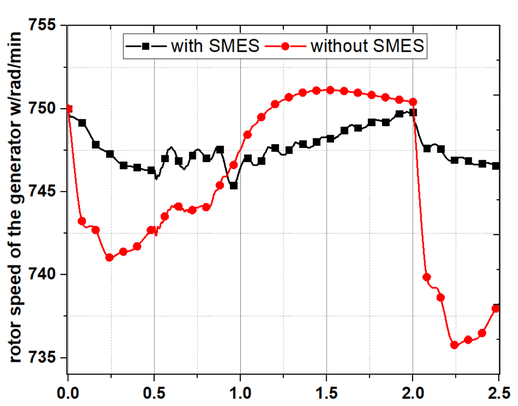
The block diagram of the SMES system

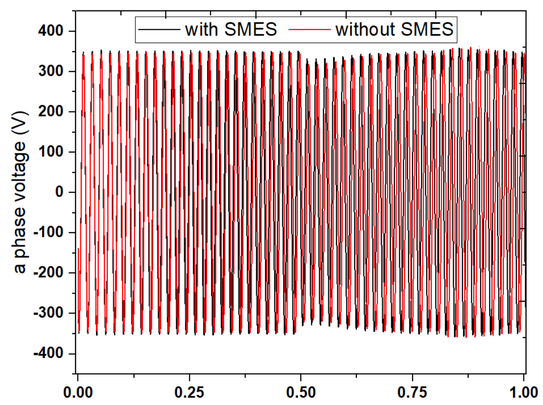
The capacitor acts as a stabilizer to support the voltage of the VSC and the chopper. The two parts of the circuit make the voltage across the capacitor stable in a value by constantly charging and discharging the capacitor. When power is required by the grid, the superconducting magnet charges the capacitor by controlling the chopper. And the energy will be reversed to the grid through VSC operating in the invertor mode. A double-loop control with the current inner loop and power outer loop is introduced to control the VSC.

III. Parameter Setting and Simulation results

TABLE I

	Designation	Value
Generator	Rated capacity	2.85MVA
	Rated voltage	450V
	Rated frequency	50HZ
	Pole pairs	4
propulsion motor	Rated capacity	2.75 MVA
	Rated Voltage	3000V
	Rated frequency	50HZ
	Pole pairs	6
SMES system	Inductance value	1 H
	Maximum output current	2000A





Ⅳ. Conclusions

The analysis of the startup of a high-capacity induction motor in a simplified electric ship power system is presented in this paper. Superconducting magnetic energy storage (SMES), which has a very fast time response, is used as energy storage module. A comparison study on two situations, with and without SMES, has been carried out in Matlab/Simulink. The results show that SMES system can well track the power demand of ship power system. SMES system helps steady the rotor speed of the generator which guarantees a smaller frequency fluctuation of the power system. In addition, better starting performance of the motor is gain with the access of SMES system.