Faults Simulation of Ship Zonal Electrical Distribution System

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Abstract

This paper focuses on short-circuit faults simulation experiments for shipboard zonal electrical distribution system based on Matlab/Simulink. Firstly, this paper introduces the research background and existing research work on the simulation of ship power system. Next, this paper describes the topology and related configuration of the ship zonal electrical distribution system set up in Simulink. Then, this paper introduces the experimental results of various types of short-circuit fault simulation of the ship zonal electrical distribution system, including single-phase, two-phase and three-phase short-circuits. The experimental results show that the simulation effect is in line with the actual situation, and it can be used as a reference for further research.

Keywords

Shipboard; Zonal electrical distribution; Simulink; Faults simulation.

1. INTRODUCTION

Modern ships are developing in the direction of electrification, and high-power propulsion motors have replaced the traditional internal combustion engines [1], and the ship electric power system has become the main power system of the ship [2], which not only reduces the carbon emission of the ship to protect the environment, but also improves the flexibility of ship maneuvering control [3]. To further improve its performance, the topology of ship power system has changed from radial type to area distribution type, and a variety of topologies based on area distribution type have been generated, such as DBDB topology, ring bus topology, BAAH topology, Hexagonal topology, and Rhomboid topology, etc [4]. Therefore, the structure of modern ship power system will be more and more complex and its role will be more and more important.

Since various types of experiments cannot be performed on actual ship power systems, simulation using computer software has become the main research method for ship power systems. Therefore, the simulated ship power system must be in line with or close to the operating conditions of the actual ship power system, and must be accurate and practical, otherwise the simulation experiments will have no practical significance, and the simulated ship power system can not be used for further research such as control. There have been a number of related studies on the simulation of ship power system. Paper [5] used PSCAD to simulate the dynamic characteristics of an all-electric ship, paper [6-7] simulated a low-voltage hybrid ship power system, paper [8] used Simulink to simulate a medium-voltage dc ship power system, and paper [9] used the hardware platform HIL to simulate a dc area-distributed fuel cell ship. Ships are prone to faults in the power system when sailing at sea, which can threaten the safety of the ship, so it is necessary to simulate the ship power system faults, which can provide a basis for further research such as fault isolation, fault recovery and so on. This paper focuses on the simulation of short-circuit faults in AC zonal electrical distribution type ship power system.

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2. SYSTEM CONFIGURATION

The research in this paper uses the Simulink/Simscape simulation platform in the MatlabR2023b software to build the ship power system model of Fig. 1 and performs short circuit faults simulation based on this model.

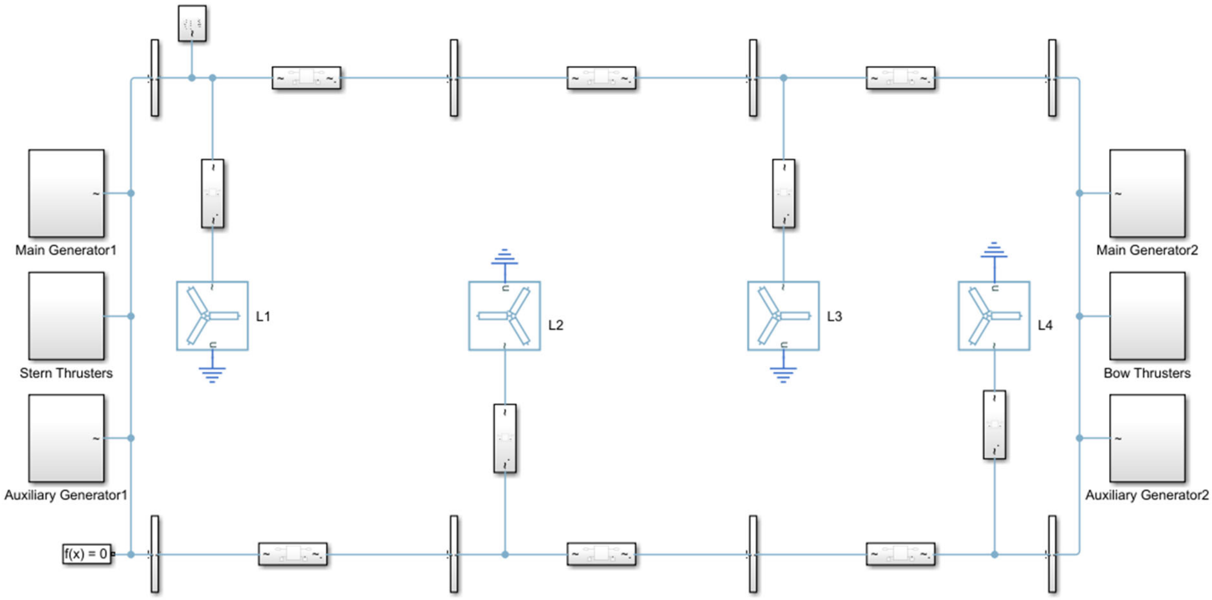

Figure 1. AC four-zone ship power system

The simulation model is an AC four-area ship power system with AC transmission and distribution and a ring bus zonal electrical distribution topology, which references the design architecture of [10]. The power system is mainly divided into four zones, including a main turbine generator, an auxiliary diesel generator and zone loads in zone 1, zone 2 and zone 3 mainly for zone loads, and zone 4 including a main turbine generator, an auxiliary diesel generator and zone loads. There are also two propulsion motors to power the ship and ten cables. The parameters of each power system unit are described below.

Firstly, the parameters of power generation unit. The parameters of the two main turbine generators are as follows: rated apparent power P is 30MVA, rated voltage V is 4160V, rated electrical frequency f is 60Hz. The parameters of the two auxiliary diesel generators are as follows: rated apparent power P is 5MVA, rated voltage V is 4160V, rated electrical frequency f is 60Hz.

Secondly, the parameters of the transmission and distribution lines. Ship power systems mainly use cables as transmission lines, and the main parameters of cables are as follows: frequency f is 60Hz, resistance R is 0.02Ohm/km, inductance L is 0.5mH/km, mutual inductance is 0.1mH/km, line-line capacitance is 0.3uF/km, line to ground capacitance is 0.1uF/km.

Finally, there are load parameters, and the loads are divided into special loads and general loads. Special loads are dynamic loads, mainly propulsion motors. General loads are static loads, mainly area loads. The parameters of the propulsion motor are as follows: rated apparent power P is 20MVA, rated voltage V is 4160V, rated frequency f is 60Hz. The loads in zone 1 and zone 4 are purely resistive R loads and their active power is 5MW. The loads in zone 3 and zone 4 is inductive RL loads, their active power is 10MW and their passive power is 700KWV*A.

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3. SIMULATION RESULTS AND ANALYSIS

Firstly, the simulation of the ship's power system startup is carried out, the simulation time is 10s in total, and the propulsion motor is started at 3s. The following two diagrams show the waveforms of the important signals of the generator and the motor.

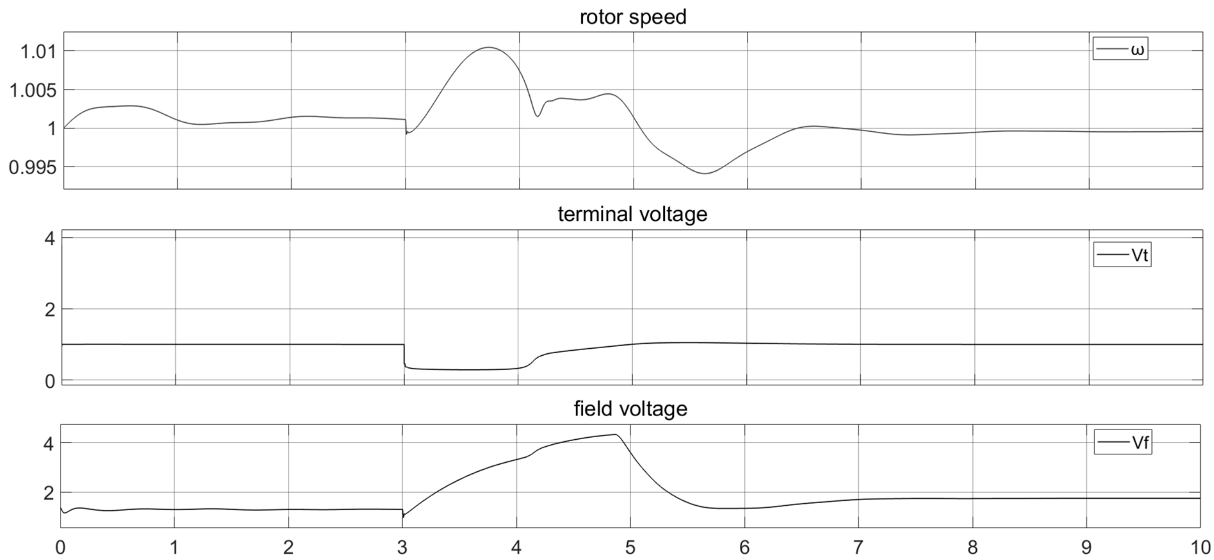

Figure 2. Generator signals waveform

From Fig. 2, when the high power propulsion motor is connected to the system at 3s, the rotational speed, terminal voltage and excitation voltage of the generator fluctuate, but all of them are stabilized at a new value after a few seconds, which indicates that the power system is stable.

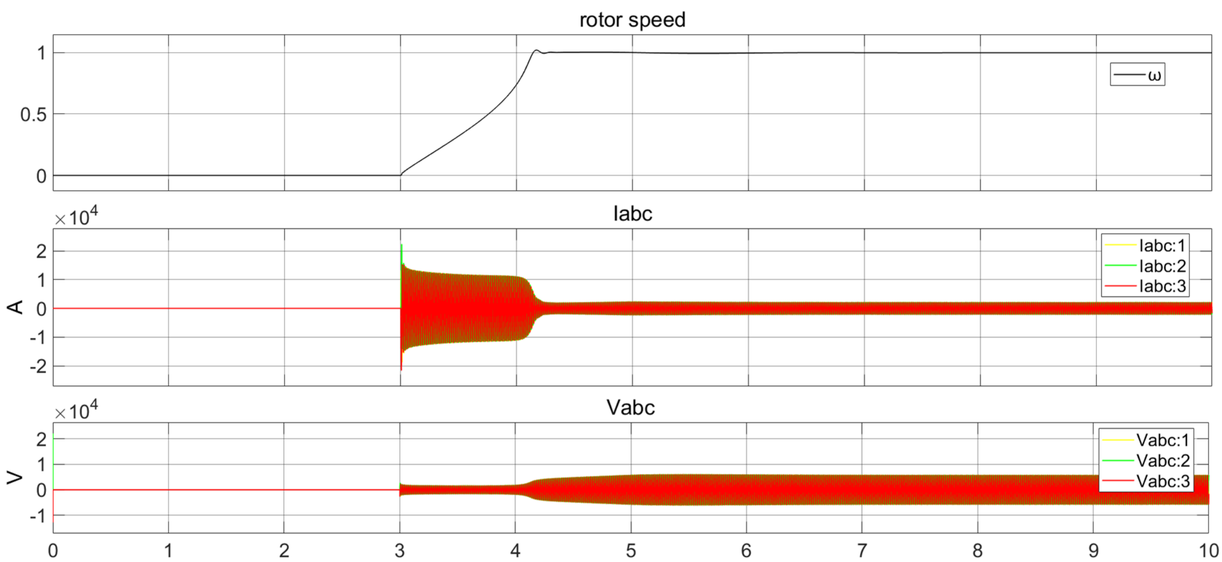

Figure 3. Propulsion motor signals waveform

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As can be seen from Fig. 3, the high-power propulsion motor starts to start operation after accessing the system to obtain electric energy in 3s, the rotational speed reaches the rated value in about 4s, and the terminal voltage and stator current are also stabilized at basically.

Because the simulated system is working normally after startup, we can simulate the short-circuit fault on this basis, we set single-phase ground fault, two-phase short-circuit fault and three-phase short-circuit fault of the distribution line at the fault node at 5s, respectively, and the fault lasts for 1s. the results of the simulation are shown in the following figures.

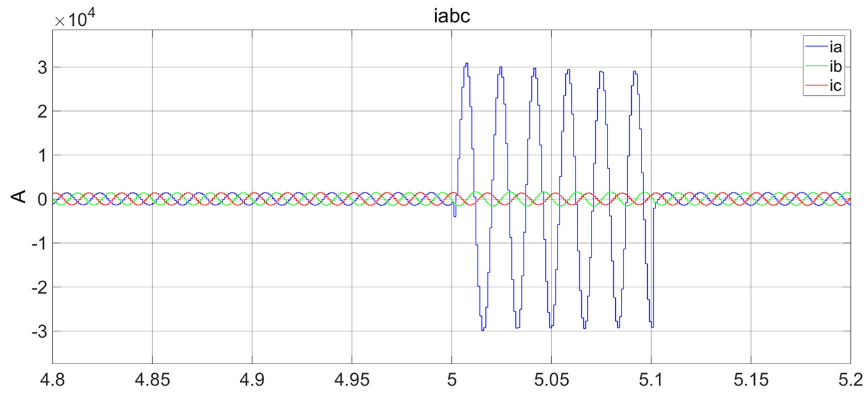

Figure 4. Single-phase ground fault

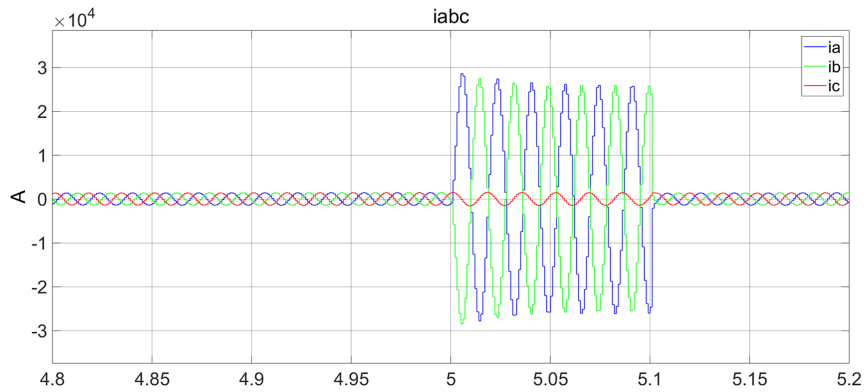

Figure 5. Two-phase fault

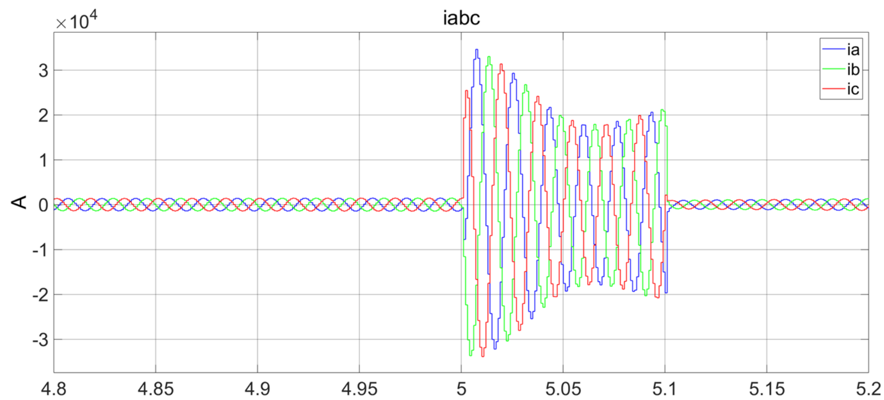

Figure 6. Three-phase fault

Figure 4 simulates a distribution line phase A ground fault. From the figure it can be seen that phase A current in 5s suddenly increased to more than ten times the normal current value. Figure 5 simulates the fault of short-circuiting phase A and phase B of the distribution line, and it can be seen from the figure that the current of phase A and phase B after short-circuiting phase A and phase B increases to more than ten times of the normal current value. Figure 6 simulates a three-phase short-circuit fault in a distribution line, and the three-phase currents after the fault are all increased to more than ten times the normal value. It can be seen that the simulated short-circuit fault of the ship's power system is in line with the actual situation, the simulation is of practical use, it can be used as a reference and basis for other studies such as control studies of ship power system.

4. CONCLUSION

In this research, the ship AC zonal electrical distribution system is simulated based on Matlab/Simulink simulation platform. From the results, the simulated system is able to simulate the normal startup and short-circuit faults of the actual ship power system, and the simulation has practical value. In the later research, the focus of should be on the accuracy and speed of the simulation to improve the accurate effect of the simulation on the basis of reducing the time cost.

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