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Research on the determination method of the intermittent grounding faults of shipboard medium voltage power system

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Abstract. In order to ensure shipboard medium voltage power system work successfully. In this paper, the existence of intermittent grounding fault of the shipboard power system is analyzed and studied. Meanwhile, A simulation model of shipboard medium voltage power system with multiple branches is built on MATLAB/SIMULINK, the simulation results are analyzed, Finally, a method for judging the intermittent grounding fault is obtained.

Introduction

Intermittent grounding fault is a common fault in the ship power system. With the ship power system voltage level from low voltage to medium voltage, Intermittent grounding fault occurs more frequently, This not only puts forward higher requirements for the insulation and safety performance of electrical equipment, but also brings a lot of problems in the application. The ship medium voltage system contains a large number of medium voltage equipment and laying long medium voltage cable. The influence of the capacitance to ground cannot be ignored when the ship power system having a large capacitance to ground. Once the single-phase ground fault occurs, the system will produce large capacitive fault current, the grounding arc does not extinguish itself, and the system is also under the impact of arc grounding over voltage (Maximum up to 3.5 to 5 times the rated phase voltage). Meanwhile the insulating protection of electrical equipment will under over-voltage shock which caused continuous intermittent grounding faults. Over a long period over-voltage fault will reduce the reliability of cable and the insulation of engine seriously.

For the case of intermittent grounding fault occurred frequently in the ship medium voltage power system, it is very practical and necessary to find a method to determine the intermittent grounding fault. In this paper, intermittent detection method is used to judge whether the system has intermittent grounding fault. The simulation of this method is completed on MATLAB/SIMULINK.

Mathematical Model of Single Phase to Grounding Fault in ship Medium Voltage Power Network

After the A phase grounding fault occurs, the phase voltage drops to zero. Neutral voltage rises to phase voltage. If the load current and the capacitive current drop in the impedance ignored, then the A phase voltage to the ground is zero, while the B phase voltage and the C phase voltage to the ground increases to $\sqrt{3}$ times of the original, that is:

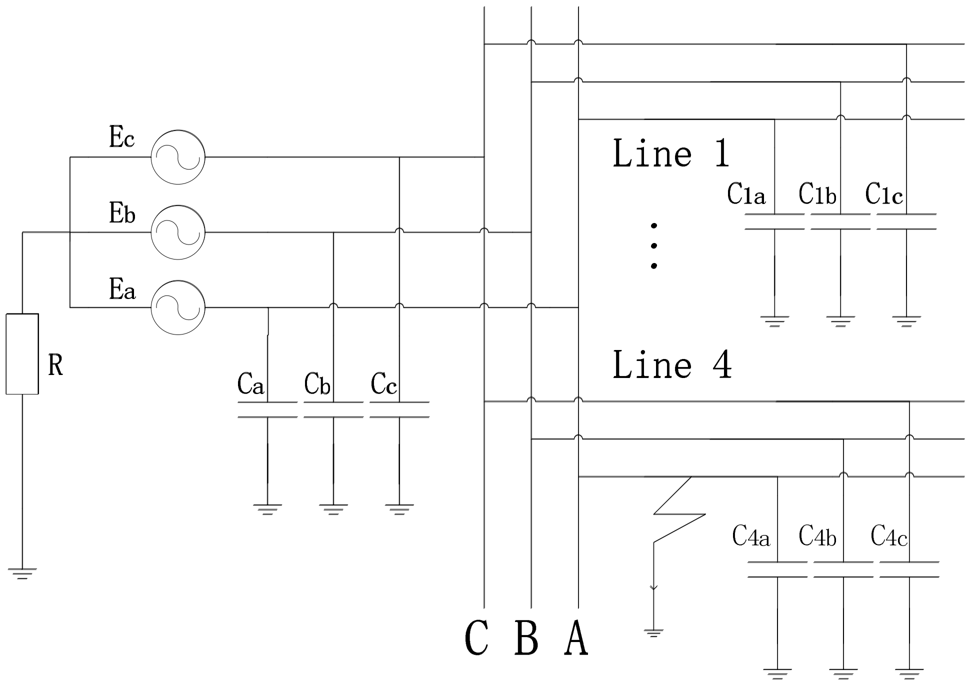


Fig. 1 Simulation diagram of single phase grounding fault in medium voltage power network.

$$\dot{U}_A = 0 \tag{1}$$

$$\dot{U}_B = \dot{E}_B - \dot{E}_A = \sqrt{3}\,\dot{E}_A\, e^{-j150^{\circ}} \tag{2}$$

$$\dot{U}_C = \dot{E}_C - \dot{E}_A = \sqrt{3}\,\dot{E}_A\, e^{j150^{\circ}} \tag{3}$$

The zero sequence voltage of fault point is:

$$\dot{U}_0 = \frac{1}{3}(\dot{U}_A + \dot{U}_B + \dot{U}_C) = -\dot{E}_A \tag{4}$$

The capacitive current generated in the non-fault phase is:

$$\dot{I}_B = \dot{U}_B\ j\omega C_2 \tag{5}$$

$$\dot{I}_C = \dot{U}_C\ j\omega C_3 \tag{6}$$

Analysis of the zero sequence current of each line:

On the non-fault line 1, capacitive current to ground of A phase is zero. B phase and C phase flow their own capacitive grounding current $\dot{I}_{B1}$ and $\dot{I}_{C1}$. Therefore, the zero sequence current of line 1 is:

$$3\dot{I}_{01} = \dot{I}_{A1} + \dot{I}_{B1} + \dot{I}_{C1} = \dot{I}_{B1} + \dot{I}_{C1} = -3\dot{E}_A\ j\omega C_1 e^{j90^{\circ}} \tag{7}$$

While on the fault line 4, capacitive current to ground of A phase is zero. B phase and C phase flow their own capacitive grounding current $\dot{I}_{B4}$ and $\dot{I}_{C4}$, the capacitive grounding current of the whole system flow back from the grounding fault point.

$$\dot{I} = (\dot{I}_{B1} + \dot{I}_{C1}) + (\dot{I}_{B2} + \dot{I}_{C2}) = 3\dot{U}_0\, C_{0\Sigma} e^{j90^{\circ}} \tag{8}$$

Brief Introduction on the Judging Method of the Intermittent Grounding Faults of Ship Medium Voltage Power System

From the chapter one, when the grounding fault occurs, the neutral point will generate zero sequence current, the characteristics of the zero sequence current of the intermittent earth fault, the single fault grounding fault and the metallic grounding fault are different. So we can put the different characteristics of the zero sequence current as the fault criterion to judge whether intermittent grounding fault occurs in the power system. First of all, the zero sequence current of the neutral point of the system is measured, then compare this value with the threshold value I_0 to judge whether the system is fault. Compare the magnitude of the zero sequence current of each line with the threshold value I_1 to judge which line is fault. Repeat the signal oversampling compared with I_1 .If the frequency that amplitude sampling value greater than the threshold value N_0, An intermittent grounding fault is identified in the system.

The Judging Method of Intermittent Grounding Fault Simulation on MATLAB/SIMULINK

To complete the transmission line modeling and parameter design is the key point to the simulation of grounding fault line selection in the ship medium voltage power system. Using MATLAB/SIMULINK SimPowerSystems toolbox can choose PI equivalent circuit module and the distributed parameter circuit module to complete the simulation design. Both of these two models take into account the problem of self-impedance and mutual impedance. According to the characteristics of the large number of branches, short transmission distance and large load of ship medium voltage power network. Meanwhile, considering the existence of the skin effect between the wire and the hull in the actual ship medium voltage power network. Finally, we choose the distributed parameter model as the ship power line network simulation model analysis to ensure that the simulation can accurately describe the frequency characteristics of RLC circuit parameters.

Below is the simulation model for the determination of intermittent grounding fault of ship medium voltage system MATLAB/SIMULINK Simulation Model

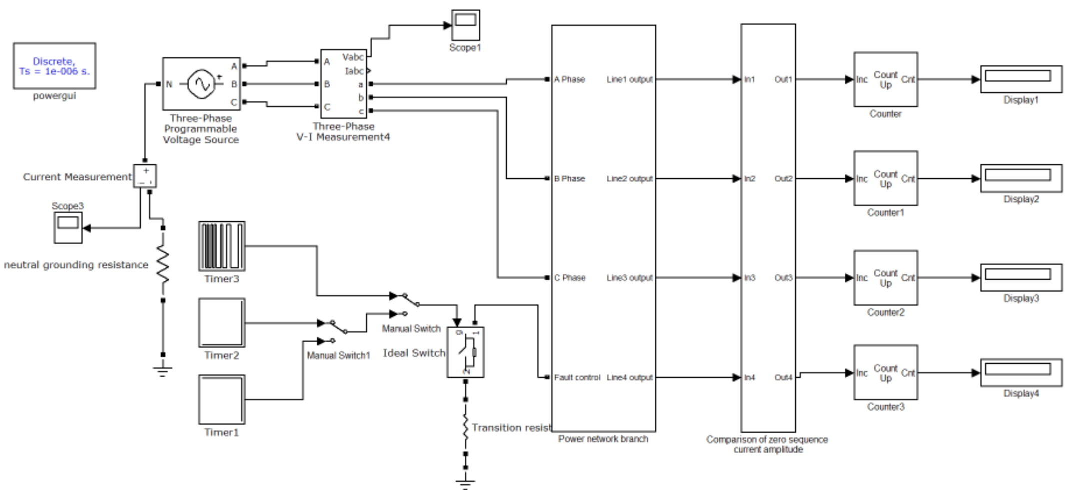
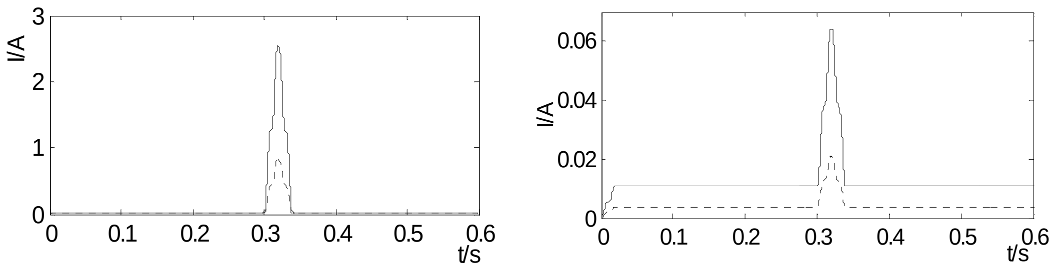


Fig. 2 MATLAB/SIMULINK simulation model for the determination of intermittent grounding fault.

As shown in Fig. 2 is a typical multi-branch network model of ship medium voltage system. Ship power network single-phase ground fault simulation modeling generally choose high resistance neutral point grounding system .The system rated voltage is 6.3kV, the rated frequency is 50Hz. Neutral grounding resistance is 1212 ohm. Line load is set to RL load. The length of cable in distributed parameter model is 0.5km which is chosen as the branch length. It is assumed that the ship power station is connected with four branches, and the grounding fault occurs on the fourth line. In this paper, according to the characteristics of the grounding fault of the shipboard power system, the ideal switch model is used as the ground fault model. By setting reasonable time parameters, the ideal switch can be controlled to achieve simulating grounding fault.

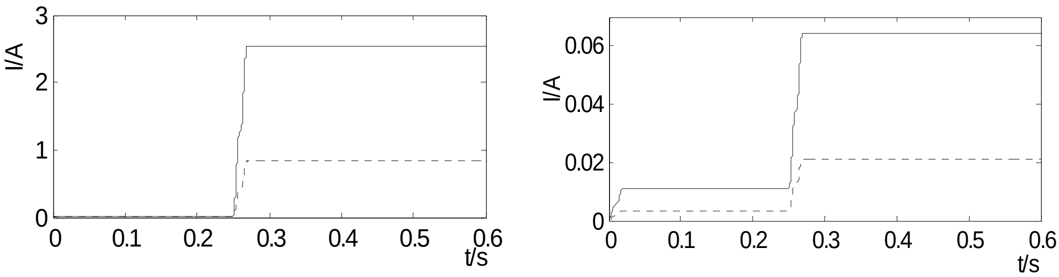
Under the conditions of the simulated transition resistance of 500 ohms and 20000 ohms, three different fault modes are set up respectively, which are the single grounding fault, the metallic grounding fault and the intermittent earth fault. The time window for collecting data is set to 0.6s. For fault mode A, The fault starts at 0.3s, then ends at 0.32s; for fault mode B, the fault starts at 0.25s; for fault mode C, faults occur within periods of time, these time periods are from 0.01s to 0.05s， from 0.07s to 0.09s, from 0.12s to 0.15s， from 0.18s to 0.2s,from 0.26s to 0.29s, from 0.34s to 0.4s， from 0.5s to 0.55s. When the transition resistance is 500 ohms, set the threshold value of zero sequence current as 1.5A; When the transition resistance is 20000 ohms, the threshold value is 0.04A. The frequency threshold value is set to 5 times, once more than 5 times, the occurrence of intermittent grounding fault alarm.

The zero sequence current and the zero sequence current amplitude of the fault line are collected in three different fault modes. The waveforms are collected as shown below.



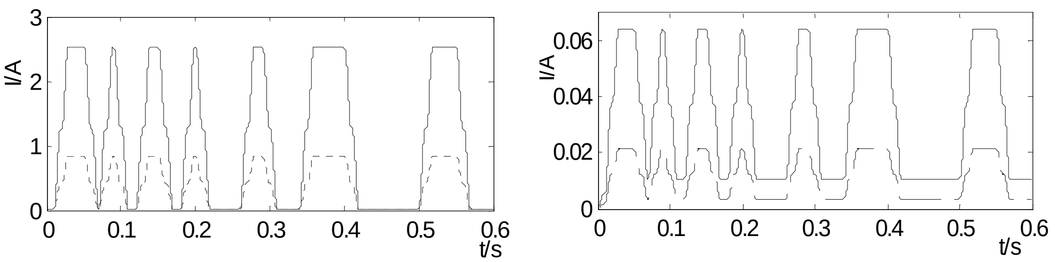
(a) Transition resistance of 500 ohms (b) Transition resistance of 20000 ohms

Fig. 3 Amplitude of zero sequence current in fault mode A.



(a) Transition resistance of 500 ohms (b) Transition resistance of 20000 ohms

Fig. 4 Amplitude of zero sequence current in fault mode B.



(a) Transition resistance of 500 ohms (b) Transition resistance of 20000 ohms

Fig. 5 Amplitude of zero sequence current in fault mode C.

As shown in Fig. 3, Fig. 4 and Fig. 5, the dotted line represents the zero sequence current amplitude curves of non-fault branches, the solid line represents the zero sequence current amplitude curves of fault branches.

When a single-phase ground fault occurs at a point of a transmission cable in the ship power network, when the grounding fault occurs, the zero sequence current amplitude of the fault branch is larger than that of the non-fault branch, which can be determined whether intermittent grounding fault occurs or not by the acquisition and processing of the zero sequence current of each line.

Within 0.6 seconds of detection time, fault mode A and fault mode B in the transition resistance of 500 ohm and 20000 cases are only once more than zero sequence current amplitude threshold, and the fault mode C has 7 times more than zero sequence current amplitude threshold in the transition resistance of 500 ohms and 20000 ohms. It exceeded the threshold of 5. So it is judged that the fault mode C has intermittent grounding fault.

Conclusion

Based on the numerical analysis on the zero sequence current of the single phase grounding fault in the shipboard power system and the experimental simulation of the fault simulation platform on Matlab/Simulink, a method is found to determine whether there is an intermittent grounding fault in the shipboard power system during the transition resistance change in the range from 500 ohms to 20000 ohms, This provides a feasible solution for the rapid and accurate location of the ground fault, and it also improve the reliability of the ship power system greatly.

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