Pan-Boolean Algebraic Simulation of stage current Protection in 20kV Distribution Network

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Abstract: In this paper, the 20kV power network is used as the design concept, and the simulation model of relay protection of single power supply branch is built by using MATLAB/simulink, and the action characteristics of the protection device are monitored by using pan-Boolean algebra. The simulation waveform of the pan-Boolean monitoring model and the waveform obtained from the relay protection simulation model are compared and analyzed to observe the internal action mechanism of the protection device and to understand the action principle of the protection device deeply.

1. Introduction

At present, most of the intermediate links between high and low voltage distribution networks in China are 10kV voltage levels. However, due to the rapid development of national economy and the continuous improvement of load level, the traditional 10kV voltage level has many disadvantages, such as insufficient power supply radius, large network loss, serious line voltage loss and so on [1].Therefore, it is imperative to upgrade the traditional 10kV voltage-level grid to 20kV grid in the future development of power network planning. Therefore, the research of relay protection for 20kV power network is still worthy of further study.

For the low voltage distribution network under 35kV, the common line protection is stage current protection, the equipment is simple and reliable, the cost is relatively low and can meet the requirement of quick and effective fault removal.

2. Simulation Model Building and Parameter calculation

A single power supply branch with protective device is selected here to calculate the operating current value of each section of the protection device. The schematic diagram of the single power supply single branch model is shown in figure 1.

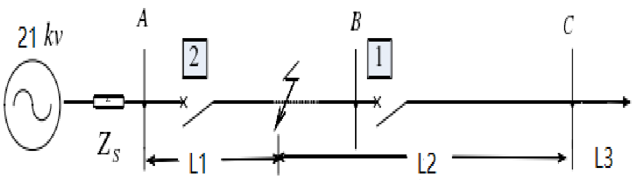

Fig. 1 simplified schematic diagram of single branch network

The power supply voltage grade of the system is U_N=20kV. Considering that the voltage of the first section of the short line is generally 1.05U_N,the power supply is set at 21 kV. As shown in figure 1, the line consists of three parts, which $L_1 = L_2$=10km, L_3=5km, the unit impedance of line $z_1 = 0.4\Omega / km$, and $Z_{s.\max} = 3\Omega$, $Z_{s.\min} = 2\Omega$. Among them, the correlation coefficient used to calculate the operation value of current protection is as follows: K_{rel}^{I}=1.25, K_{rel}^{II}=1.1, K_{rel}^{III}=1.2, K_{ss}

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=1.5, K_{re}=0.85[4].According to the references [4],[5], the results of setting the action current of each segment of the stage current protection are as follows:

1) Current quick break protection:

$I_{set.1}^{\mathrm{I}} = K_{rel}^{\mathrm{I}} I_{k.\max}$=2.015(kA), According to the theoretical design, the current protection section I is time-free, but in the practical simulation application, for convenience of observation, the action value is taken as follows. t_1=0.01s.

2) Limited current quick break protection:

$I_{set.2}^{\mathrm{II}}$=1.18(kA), according to the theoretical value the action time limit should be setting as $t_2 = t_1 + \Delta t$=0.5s, however, in this design, for the convenience of simulation observation, the time limit of its action is t_2=0.2s.

3) Timing limit overcurrent protection:

$I_{set.1}^{\mathrm{III}}$=0.52(kA). The requirement of action time limit is similar to that of protection section II. In this simulation design t_3=0.5s is used to instead of the actual theoretical value of 1 s.

The MATLAB/simulink simulation model of stage current protection is built, and the internal protection of each segment of the model is encapsulated.Using the fault module, we can set up the short circuit fault in different position of the circuit, and simulate and verify the action effect of each segment of current protection.

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3. Modeling and Simulation of pan-Boolean Algebra

3.1 pan-Boolean algebra modeling

The principle of pan-Boolean algebra is used to monitor the action of the A,B,C three phase protection. In this paper, the three phases of A,B,C, are expressed by means of X_1, X_2、X_3.Besides, x_1^1 represents the current-break protection of phase A protection, x_1^2 represents the time-limited current quick-break protection of phase A protection , x_1^3 represents the time-limited overcurrent protection of phase A protection . The B-phase and C-phase conditions are similar and will not be elaborated one by one. Y_1、Y_2、$\cdots Y_9$ respectively represent the nine protection devices of the three phases A, B, and C, where Y_1、Y_2、Y_3 correspond to the three protection devices of phase A, and so on. Each phase protection has two states, action and no action, which are denoted by y_1^1、y_1^2, respectively. Where y_1^1 denotes the first-stage protection quick-break protection action of phase A protection, $y_1^2 = 1$ denotes that the first stage of phase A protection does not operate, and the protection states of the subsequent phases are similar.

3.2 Simulation operation and result analysis

Build a pan-Boolean monitoring model, run the simulation model, combined with simulation images to verify the correctness of the pan-Boolean model. For stage current protection, the action of the protection device is mainly verified when the circuit occurs interphase short circuit fault. The following three sections of current protection are verified separately, and different short circuit faults are verified, as described below.

Set the line parameters as follows: $Z_s = 3\Omega$; The internal parameters of the L1 line are

$R = 1.33\Omega$、$L = 12.764 \times 10^{-3} H$; The internal parameters of the L2 line are $R = 0.655\Omega$, $L = 6.382 \times 10^{-3} H$ .Using the three-phase fault module to set the fault type to A and B two-phase short circuit, the running simulation can obtain the waveform diagram as shown in Figure 2~5.

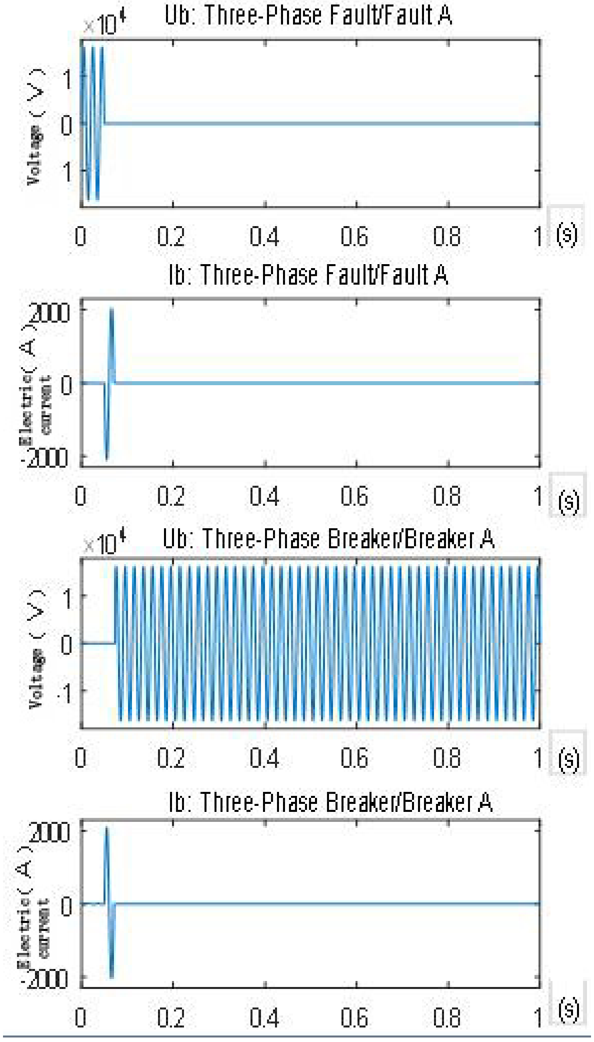

Fig. 2 Waveform diagram of current protection I section action

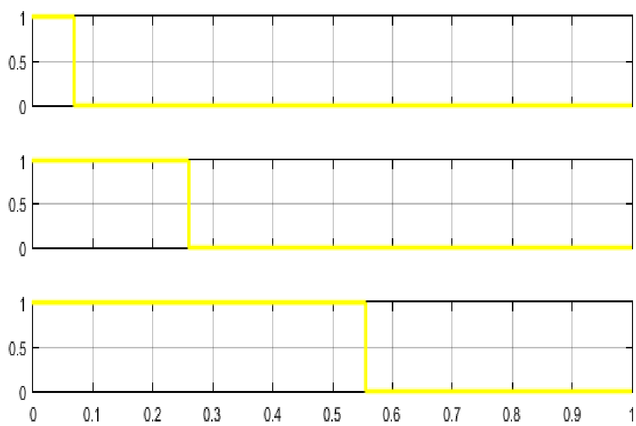

Fig.3 A phase protection device action waveform

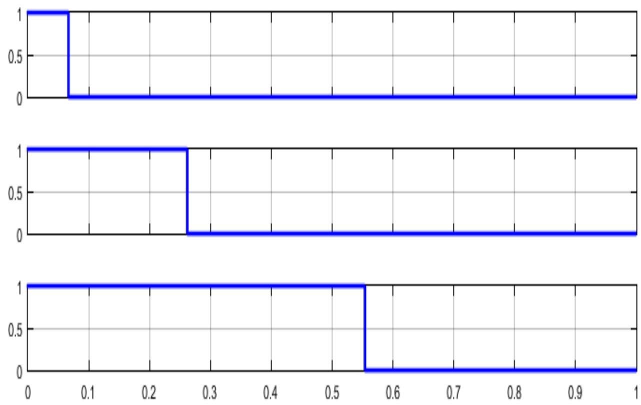

Fig. 4 B phase protection device action waveform

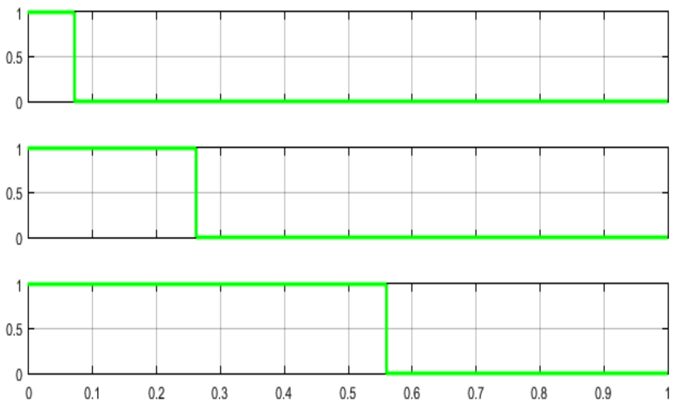

Fig. 5 C phase protection device action waveform

According to Figures 4~6, in the case of A and B phase faults, the protection of phase A and phase B is normally started, while the phase C protection is inactive, and the fault occurs in the range of protection I, the protection of phase A and phase I There will be motion signals in sections II and III. By analyzing Figure 4, it can be seen that during the current protection I section action, the protection segment II and the third segment also have the action trip signal, which is consistent with the state lamp action, except that the action time limit has a delay. When the line fails at 0.05s, a large short-circuit current occurs. The protection device acts after a delay of 0.01s. The circuit breaker trips to protect the I segment from successful operation, while the protection time for the protection segment II and the protection segment III is 0.26s with 0.56s seconds, which is consistent with the simulation parameters, indicating that the pan-Boolean model runs successfully.

4. Conclusion

In this paper, the protection device of the relay protection simulation model is modeled by using the generalized Boolean algebra to monitor the action characteristics of the protection device. The correctness of the monitoring effect is verified by comparison with the short-circuit current waveform. Observing the action waveform of the protection device can better understand the coordination relationship between the segments of the phase current protection, which can deepen our understanding of the phase current protection principle.

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