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The Modeling and Simulation Research on High-Voltage Transmission Line Distance Protection Devices

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Abstract. Transmission line protection is a very important part of the power system. In order to effectively study the distance protection of high-voltage transmission lines, this paper introduces the setting and operation of distance protection, build the mode with Simulink tool box in the software of Matlab, and simulate the mode by S functions. The simulation results illustrate the Matlab software can effectively reflect the behavior of the distance protection when there are some faults in the simulated transmission line, which proves a simple and effective method to research the relay protection in the power system.

1. Introduction

The relay protection is an important part ^[1] in power system in which the distance protection can fast response the impedance between the fault position and the protection position ^[2~3]

Analysis of electric power system and the threat to the safe operation of the abnormal situation, and obtain the corresponding solutions, power system mainly USES the contact of the relay to ensure the electric power system and components from related damage, this is the process of power system relay protection process. The main task is to: when power system malfunction or abnormal condition, the minimum time and scope, independent filter malfunctioning equipment, and transfer the signal by the operator to abnormal situation, and finally process to reduce the damage to the equipment near area power supply adverse interference. Power system operation process, the external factors (such as weathering, hail, etc.), internal factors (insulation aging, damage, etc.) and operation and so on, they will lead to different kinds of faults and abnormal operating situation has, common fault: single-phase grounding; Three phase grounding; Two phase ground; Interphase short circuit; Short circuit, etc. Power system relay protection mainly experienced mechanical and electrical type, rectifier type, transistor, integrated circuit type and microcomputer protection five stages. Relay protection device mainly have five kinds of performance: (1) security: in shouldn't action, not false move; (2) the stability: in this action, not refused to move; (3) by high efficiency can be timely filter corresponding fault and abnormal situation; (4) selective: given the area filter breakdown, assure trouble-free area power maximization, and not the trip; (5) compliance: can describe the performance of the relevant fault height, generally with the sensitive coefficient description.

The power grid with 110kV or below uses the distance protection as the main protection in the power transmission line ^[4~5], which can instantaneously separate 85% faults in the transmission line. With the development of science and technology, the micro distance protection is widely applied in power system. Compared with traditional distance protection, the micro distance protection utilizes



automatic control technology which greatly increases the flexibility, reliability, selection and response speed. The increasing development of DSP control technology opens new directions for the adaptive power security protection systems.

2. Distance protection analysis among phrases

2.1. Distance protection procedure

The mechanism of the distance protection is to distinguish the system whether in normal state or fault state through the impedance measurement, which can ensure the protective tripping for target protection. The control mode of the micro distance protection devices is shown in figure 1.

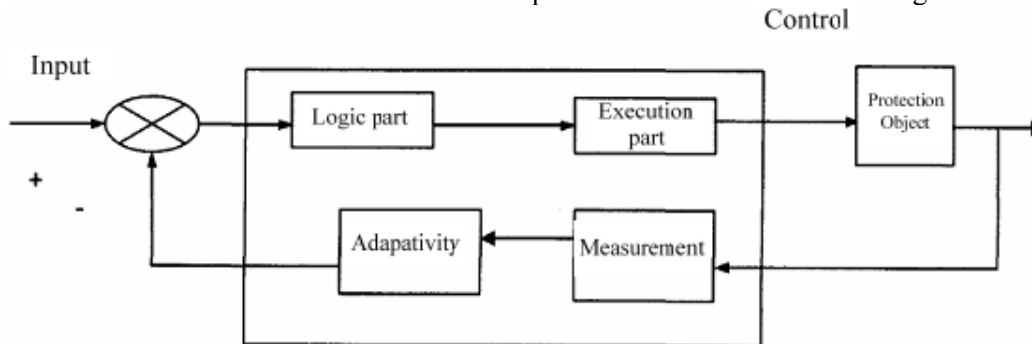


Fig. 1 the control scheme of the micro distance protection devices

The function fulfillment procedure of the micro distance protection devices in figure 1 is as follows.

(1) The states of the protected lines, such as normal, fault and fluctuation are identified based on the electrical parameters in the line and the dynamic and static conditions.

(2) Under the premise of ensuring the state of the protective line, the decisions of the micro distance protection devices are very important which can evaluate the fault property according to the previous fault analysis experience and computer database support in order to gradually increase the protection behavior performance.

(3) Based on the step (1) and (2), the relay will decide whether to trip according to the operation states and selected protection method.

2.2. Distance protection principle among phrases

The distance protection devices are consisted of impedance elements. Normally the impedance measurement elements between phrases apply 0 connection method. The benefits of the connection are that the distance between the fault position and the protection installation can be accurate measured when there are faults between phrases. When the properties of the impedance elements are the same, the meaning of each impedance element is as shown in table 1.

Table 1 The meaning of impedance elements 0 connection

	Impedance element 1	Impedance element 2	Impedance element 3
Um	U_{AB}	U_{BC}	U_{CA}
Im	$I_A - I_B$	$I_B - I_C$	$I_C - I_A$

When there are short circuits between phrases and shorted to ground in the transmission line, the measurement value of the protective impedance elements is:

$$Z_{m1} = \frac{U_A - U_B}{I_A - I_B} = \frac{I_A Z_{l_k} + U_{dA} - I_B Z_{l_k} - U_{dB}}{I_A - I_B} \quad (1)$$

$$= Z_{l_k} + \frac{U_{dA} - U_{dB}}{I_A - I_B}$$

$$Z_{m2} = Z_{l_k} + \frac{U_{dB} - U_{dC}}{I_B - I_C} \quad (2)$$

$$Z_{m2} = Z_{l_k} + \frac{U_{dC} - U_{dA}}{I_C - I_A} \quad (3)$$

In the above three equations, $Z_1 l_k$ is the short circuit between the fault position and the protective installation, which can be replaced by Z_k ; Z_1 is the positive impedance per kilometer; l_k is the distance the fault position and the protective device installation position; U_{dA} , U_{dB} and U_{dC} are three-phase voltages to ground; I_A , I_B and I_C are three-phase fault current.

When the metallic three-phase short circuits happen in the protective positive direction, the three-phase electricity from the installation of the distance protective devices is symmetric, that is: $U_{dA}=U_{dB}=U_{dC}=0$.

$$\begin{cases} U_A = I_A Z_k \\ U_B = I_B Z_k \\ U_C = I_C Z_k \end{cases} \quad (4)$$

The current and voltage in the three impedance elements are expressed as:

$$U_{m1} = I_A Z_k - I_B Z_k, I_{m1} = I_A - I_B \quad (5)$$

$$U_{m2} = I_B Z_k - I_C Z_k, I_{m2} = I_B - I_C \quad (6)$$

$$U_{m3} = I_C Z_k - I_A Z_k, I_{m3} = I_C - I_A \quad (7)$$

Therefore, the conditions of the three impedance elements are the same so just discussion one impedance element is enough. Take the equation (5) as an example, the measurement impedance is expressed as:

$$Z_{m1} = \frac{U_{m1}}{I_{m1}} = \frac{I_A Z_k - I_B Z_k}{I_A - I_B} = Z_k = Z_1 l_k \quad (8)$$

The above equation can well represent the relationship between Z_{m1} and the distance l_k . If there are metallic shorts in the positive direction, such as there is short circuit among A, B and C. There is:

$$I_B = -I_C, I_A = 0 \quad (9)$$

The three-phase voltage in the installation position is:

$$\begin{aligned} U_A &= E_A, U_B = I_B Z_k + U_{dB}, \\ U_C &= I_C Z_k + U_{dC} \end{aligned} \quad (10)$$

Because $U_{dB}=U_{dC}$, the measurement of the three impedance elements can be represented as:

$$Z_{m1} = \frac{U_A - U_B}{I_A - I_B} = Z_k + \frac{E_A - U_{dB}}{-I_B} \quad (11)$$

$$Z_{m2} = \frac{U_B - U_C}{I_B - I_C} = Z_k = Z_1 l_k \quad (12)$$

$$Z_{m3} = \frac{U_C - U_A}{I_C - I_A} = Z_k + \frac{U_{dC} - E_A}{I_C} \quad (13)$$

From the above equations, when the circuits between phrases B and C is shorted, the impedance element can reflect the distance between the shorted circuit and the protection device installation position is l_k . If there is shorted circuit between other two phrases, the corresponding impedance element can accurately reflect the distance l_k .

3. The establishment of distance protection model

3.1. Model establishment

Normally, the high-voltage transmission line has the characteristics of long line, large distribution capacitance, small effective resistance and inductance, and high transmission power which is hard to use practical experiments to solve all of the problems and the cost is quite high. Thus, the transmission line model close to the practical problem is effective replacement for the experiments.

The short circuit fault model in the power system can be modeled by Simulink and power system module in the Matlab as shown in figure 2. Various kinds of fault types can be set flexibility by

changing the components parameters, fault positions and time in the diagram which can simulate multiple fault situations in the power system.

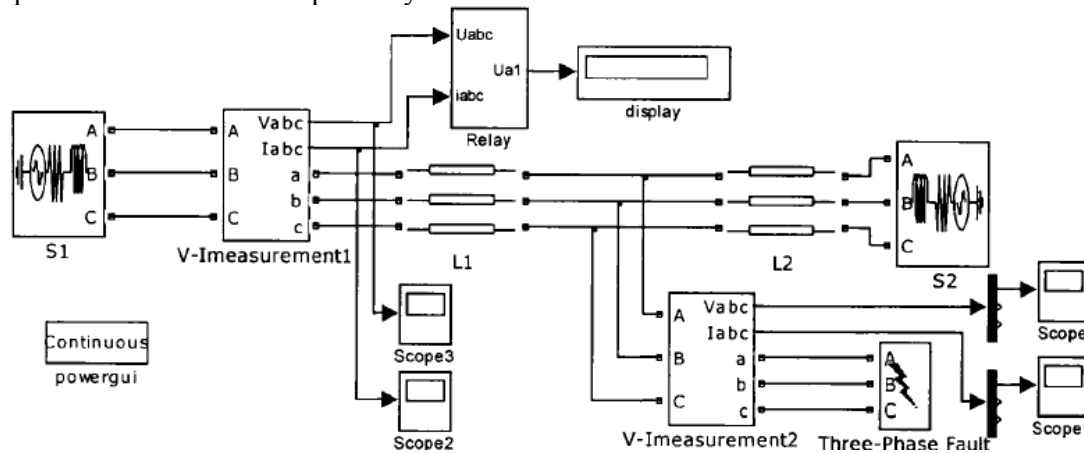


Fig. 2 the fault simulation diagram in the transmission line

This transmission line fault model is consisted of voltage power source, transmission line, oscilloscope, three-phase voltage-current measurement components, relay packaging and fault generator. When customize the Simulink module in the transmission line distance protection, M files is used to program S functions. The key is to initialize the module characteristics while programming the S functions. The S functions should provide initialization conditions in order to identify S functions by Simulink which can be completed by mdlInitializeSizes. The flow chart of the distance protection M program is as shown in figure 3.

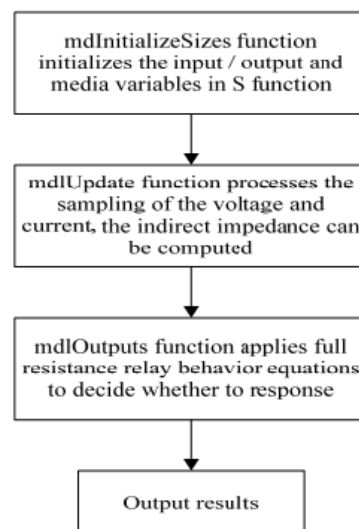


Fig. 3 Distance protection M program flow chart

3.2. Parameter configuration for the simulation

According to the practical and system simulation requirements, the parameters configuration is set as follows:

- ① Power source: amplitude is 500kV, phrased angle is 120° , frequency is 50Hz and $X/R=7$;
- ② Transmission line: the total length is 300km, the resistance of zero-sequence and positive-sequence is respectively $r_0=0.1148\Omega/\text{km}$ and $r_1=0.0208\Omega/\text{km}$, the inductance of zero-sequence and positive-sequence is $l_0=2.2898\text{mH}/\text{km}$ and $l_1=0.8987\text{mH}/\text{km}$, the capacitance of the zero-sequence and positive-sequence is respectively $c_0=0.00523\text{F}/\text{km}$ and $c_1=0.0129\text{F}/\text{km}$;
- ③ the output signal of three-phase voltage-current is in the form of complex number;
- ④ the sampling mode of oscilloscope is 1:1;
- ⑤ The phrased comparison relay is consisted of reference voltage module, operation voltage, operational space interface module, and phrased comparison module. The default phrased angle

parameter in Matlab is radian. Thus, the angle should be converted to radian when set the configuration parameters. When display the angle difference between the operational voltage and reference voltage, the radian data should be converted to angle data, then it's connected to the I/O port which considers the whole device as a system package.

4. Simulation analyses

The built model is simulated. Figure 4 and 5 is the faults simulation waveforms of B and C two-phase short circuit at 220km and 255km respectively in the transmission line; Figure 6 is the A, B and C three-phase short circuit fault simulation waveforms at 120km. Figure 4 and the figure (a) in figure 5 and is the three-phase current waveform when the faults happen; figure (b) in figure 5 is the behavior waveforms of the distance protection devices. (a) in figure 6 is the three-phase current waveforms when B, C is two-phase shorted to ground. (b) is the behavior waveform of the distance protection devices.

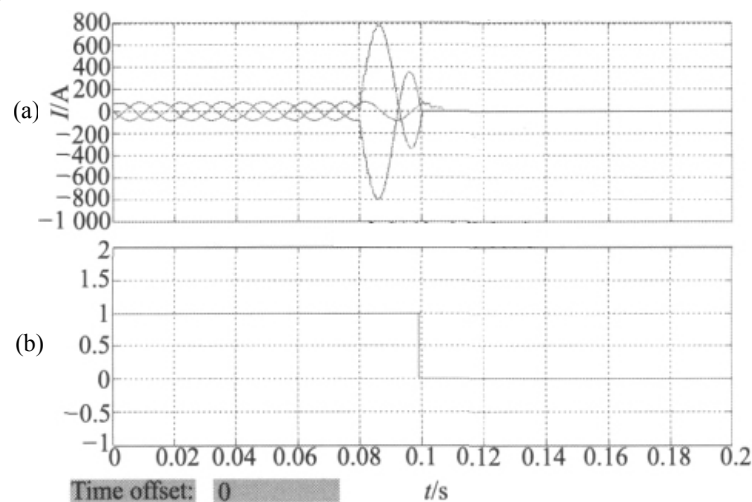


Fig. 4 Two-phase short circuit waveform graph of B and C in distance 220km

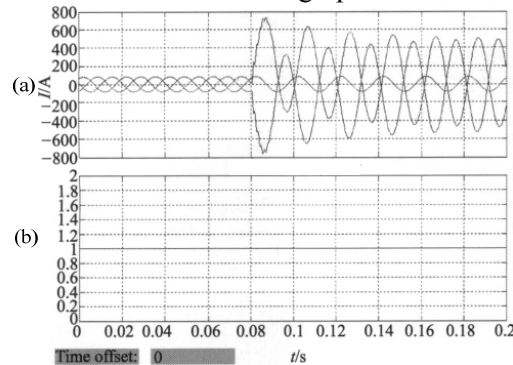


Fig. 5 Two-phase short circuit waveform graph of B and C in distance 255km

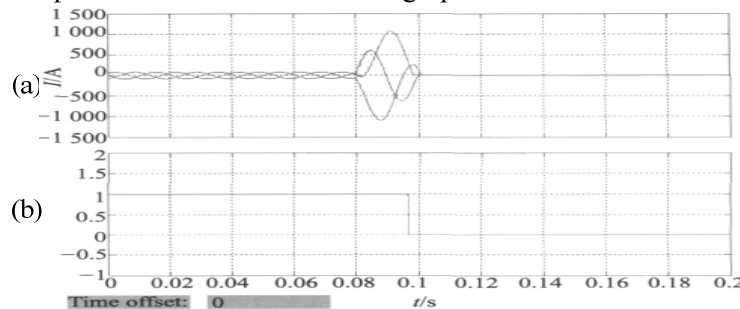


Fig. 6 Three-phase short circuit waveform graph of A, B and C in distance 220km

From the simulation waveforms in figure 4 and 6, when the faults happen at 220km, the distance protection devices can finish the tripping operation in 20ms. From the figure 4 and 5, when the faults

happen at 255km outside the whole rang (assume the length of the whole line is 240km), the distance protection devices will not response. The simulation results illustrate the S function in Matlab can well simulate the behavior of the distance protection devices when there are faults in the power transmission lines.

5. Conclusions

The power system is a very complex dynamic system and modeling simulation for distance protection research in high-voltage is effective. Matlab software has very strong extension functions and computation capabilities which is quite suitable for complex model computation and simulation. This paper explains and analyzes the method and steps for distance protection, builds a practical model and applies S functions to develop the simulation software which can effectively simulate the current waveforms with multiple faults and the behavior of the distance protection devices. The simulated results match the theory solutions. The proposed method provides a simple but effective method for relay protection in power system.

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