Summary of Fault Line Selection for Single-phase Grounding in Small Current Systems

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Abstract. At present, fault line selection theory of small current grounding system mainly focuses on solving the reliability problem of urban power supply system. There is little research on the line selection theory of mine distribution network, but single phase ground fault in mine distribution network will cause more harm. This paper analyzes and compares the existing fault line selection theories applicable to the mine power supply system and other industrial sites, providing theoretical guidance for the study of fault line selection in special occasions such as mines.

Keywords: Fault line selection · Small current grounding system · Mine power supply system

1 Introduction

Most of the low-voltage distributed system in China adopt neutral non-grounding system, and the faults are mostly single-phase grounding fault. The increase of the unfaulted phase voltage will endanger the weak link of insulation and seriously affect the reliability of power supplies when the system has single-phase grounding fault in neutral non-grounding system [1]. Especially in mines and other special occasions, the power supply environment is more dangerous and complex, which may lead to more serious.

At present, the research of line selection theory focuses on urban power supply system, but the research on fault line selection for special occasions such as mine is relatively few. Based on the analysis and comparison of the existing fault line selection theory which is applicable to mines and other industrial sites, this paper provides theoretical guidance for the study of fault line selection in mines and other special industrial occasions.

2 Fault Signal Characteristic Analysis of Small Current Grounding System

2.1 Steady-State Characteristics of Neutral Non-grounding System

In neutral non-grounding system, we assume that the line resistance is zero, which there is no voltage drop on the load current line, and the load is treated as constant to simplify the

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analysis. The parameters of the distribution network system are symmetrical parameters during normal operation. The three relative ground capacitors of each line are equal to C_0, the ground capacitance of bus and back power supply is C_{0S}, and each phase the power supply is represented by E_A, E_B, E_C, respectively.

When metallic grounded fault occurs in phase A of line L2, the steady-state capacitance current distribution of the system is shown in Fig. 1. As can be seen from Fig. 1, Fig. 2 and Fig. 3, steady-state capacitive current has the following characteristics [2]:

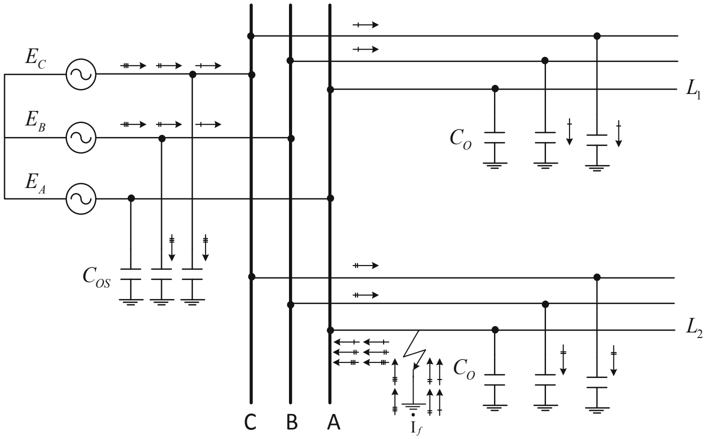

Fig. 1. Schematic diagram of single-phase ground fault

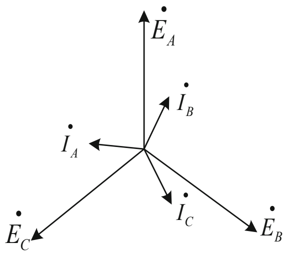

Fig. 2. Normal voltage vector relation

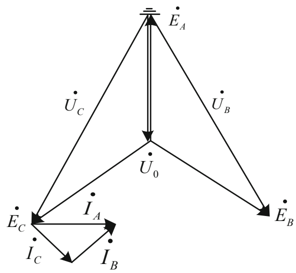

Fig. 3. Fault voltage vector relation

1. In the fault line, phase A to ground voltage drops to 0, so the capacitance current is 0. The other two phase to ground voltage rises to $\sqrt{3}$ times, and the capacitance to ground current correspondingly increases by $\sqrt{3}$ times.
2. The value of zero-sequence current in the fault line is equal to the sum of the capacitance current of the non-fault components of the whole system to the ground, and the actual direction of capacitive reactive power is line to bus.
3. The zero-sequence current of the unfaulted phase line is the grounding capacitive current of the line itself, and the zero-sequence reactive power flows from the bus to the line.

2.2 Transient Characteristics of Neutral Non-grounding System

When the neutral indirectly grounded system has ground fault, the zero-sequence current will oscillate strongly. These abundant transient signals have large amplitude and wide spectrum, which provide important criteria for identifying grounding fault. Transient characteristics of small current ground fault [3]:

1. The discharge capacitor current caused by a rapid drop in the fault phase voltage, which flows from the bus to the fault point, and the discharge is rapidly attenuated, with an oscillating frequency of up to several kilohertz.
2. The unfaulted phase voltage will rise to $\sqrt{3}$ times the phase voltage resulting in the charging capacitor current, which loops through the power supply. Due to the large inductance of the whole circuit, the charging current decays slowly and oscillates low, usually only a few hundred Hertz.

3 Fault Detection Method for Small Current Grounding System

At present, there are three kinds of fault line detection methods, namely, manual pulling method, active line selection method and passive line selection method.

3.1 Manual Wire Pulling Method

Manual wire pulling method. When an earth fault occurs, the power grid operation and maintenance personnel shall close each line one by one, and look for the fault line according to the different states after closing. This method can cause short interruption of power supply, but it is very reliable and often used in actual operation.

3.2 Active Line Selection Method

Signal injection method [4]. The method is to inject the current signal of specific frequency into the earthing circuit through the neutral point of the three-phase voltage transformer. The injected signal will be injected into the ground along the fault line through the landing site, and each line will be detected with a signal detector. When the fault occurs, the line that detects the presence of an injection signal is determined as the fault line.

The merit of this method is that it is not influenced by the arc suppression coil, does not need to install the zero sequence current transformer. It can also detect faults along the fault line with a detector to find out where the fault occurred on the overhead line. But the disadvantage is that the signal injection equipment needs to be installed. In the actual application, the fault signal is often weak and difficult to detect, resulting in misjudgment.

3.3 Passive Line Selection Method

Passive mode can be divided into fault steady-state variable line selection, fault transient variable line selection and fault transient and steady-state variable comprehensive line selection method.

Line Selection Method Based on Fault Steady State Information. Zero-sequence current amplitude method [5]. This method is based on the zero- sequence current amplitude of each line to determine the fault line. In other words, the largest amplitude is the fault line. However, the line selection may fail when the amplitude difference is not large or the bus fails. In addition, it is also influenced by unbalanced current of the current transformer, system operation mode, environmental factors and other problems. This line selection method has a small range of application and low reliability.

Zero-sequence current phase ratio method. Through fault signal characteristic analysis of neutral non-grounding system, it can be seen that the flow direction of zero-sequence current of fault line is opposite to that of healthy line. By using this characteristic, fault line can be quickly identified. However, the zero-sequence current flow of fault line is the same as that of unfaulted line when small current system is overcompensated.

Zero-sequence current group amplitude-phase method [6]. This method summarizes the above two ways of line selection. Firstly, the zero-sequence current amplitude of the line is compared, and several lines of large zero-sequence current amplitude are selected as alternative lines. Then, the phase comparison of the alternative lines is carried out. If the zero-sequence current phase of the selected line is different from that of other lines, the line is considered a fault line. If the zero-sequence current phase of each line is the same, it is judged to be bus fault. This method overcomes some disadvantages of the former two methods to some extent, but it also cannot overcome the influence of unbalanced current and transition resistance of current transformer.

Although the calculation amount of the steady-state method is small, the fault current amplitude is very small, and the current is also superimposed in the load current. The electromagnetic interference in the field is relatively large, which makes the detected fault component have a very low signal-to-noise ratio. Therefore, in the actual distribution network, the line selection method based on steady-state component is easy to cause misjudgment.

Line Selection Method Based on Fault Transient information. First half wave method [7]. There is a fixed phase relation between transient zero-sequence current and transient zero-sequence voltage at the initial stage of fault occurrence, lasting about 1/4 period. The phase polarity of the fault line is opposite, and the polarity of the healthy line is the same, so this feature can be used to identify the fault line. This method is suitable for neutral arc suppression coil grounding system and neutral indirect grounding system, and can also detect unstable grounding fault. However, the opposite polarity only holds in a very short time, and has a great influence in many aspects.

PRONY algorithm [8]. Prony algorithm can accurately analyze the fault current of grounding point. The method uses exponential fitting model for spectrum analysis. The amplitude, phase, frequency and other parameters of the transient components of fault current in the neutral non-grounding system are obviously related to the fault characteristics. The algorithm uses these characteristics to select fault line. Using prony algorithm can effectively achieve fault location, but the calculation of this algorithm is relatively large.

Line selection method of wavelet transform [9]. Wavelet transform has the reputation of "mathematical microscope" and can analyze the local characteristics of fault current signal well. Choosing the appropriate wavelet base to transform the zero sequence current, the modulus of wavelet coefficient which is much larger than the normal value can be obtained. Through the comparison of modulus, the maximum modulus is determined as the fault line.

The advantage of wavelet method is that it can be used in neutral non-grounding system and arc suppression coil grounded system. This method can also be used to deal with the situation that the fault waveform is disordered and the fault condition is complex. However, in the complex and changeable working environment of power system, all kinds of interferences are very strong and the signal-to-noise ratio is low. Wavelet analysis method is a comparative analysis of the singular points of zero-sequence current waveform, which is usually difficult to distinguish and prone to misjudgment.

4 Conclusion

This paper summarizes the method of single-phase grounding fault line selection, and introduces merit and demerit of various methods in detail, which can guide the line selection in industrial field. In the current society, whether it is urban distribution network or mine power supply reliability is becoming more and more important. With the development of fault theory research and fault signal processing, it is believed that it is not far to realize fault line selection reliably and accurately in the neutral point indirectly earth system.

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