A Fault Location Method for High-voltage Overhead Transmission Lines based on Synergy Theory

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Abstract

With the increasing scale of power system, there are more and more high-voltage long-distance transmission lines. The faults of high-voltage transmission lines have a wider impact on the power system, industrial and agricultural production and people's daily life. By then, there will be three interconnected power grids in north, middle and south China. Therefore, the high-voltage overhead transmission line can operate normally, so that the power system can supply power more reliably, and the stability of operation will be improved accordingly. Implementing effective measures to diagnose faults quickly can help to eliminate faults and play an important role in ensuring the normal operation of power system. Under the influence of some factors, if the fault occurs, it is difficult to effectively carry out fault location. This requires that the fault location method of high voltage overhead transmission line can be effectively improved. Based on the research, the application level of fault location method is effectively improved. However, the technology of microcomputer fault location has not appeared for a long time, and it needs to be improved both in theory and in practice. This paper mainly analyzes the fault location method of high voltage overhead transmission line. The application principles of impedance method and traveling wave method in fault location of overhead transmission line are analyzed. It can provide reference for fault location and troubleshooting of overhead transmission line in later period.

Keywords

High Voltage Rack; Transmission Line; Fault Location.

1. Introduction

High voltage overhead transmission line is an important part of power system. With the increasing scale of power system, there are more and more high-voltage long-distance transmission lines. The faults of high-voltage transmission lines have a wider influence on power system, industrial and agricultural production and people's daily life [1]. At the same time, the power grids in North China, Northeast China and Northwest China will be interconnected. China Southern Power Grid will be further strengthened. By then, there will be three interconnected power grids in north, middle and south China [2]. Therefore, the high-voltage overhead transmission line can operate normally, so that the power system can supply power more reliably, and the stability of operation will be improved accordingly [3]. In this paper, the fault location method of high voltage overhead transmission line is deeply analyzed. If the fault location can be carried out quickly and accurately, and the hidden danger of insulation can be found in time, the safe operation of power grid can be guaranteed technically, which has great social and economic benefits [4]. Due to the wide distribution and complex terrain, transmission lines are prone to failure. And when the overhead line failure, such as the implementation of line by line investigation, low efficiency, can not be timely troubleshooting, easy to cause a series of chain reaction. Therefore, the fault location technology and method of overhead transmission line in high voltage power grid has become a key research topic of various scientific research institutions.

In order to meet the needs of economic development, China's power grid construction is constantly increasing, and its coverage area is increasing year by year. Therefore, in order to ensure stable power supply, the power supply industry has higher and higher technical requirements for the erection of high-voltage and long-distance power grids. Implementing effective measures to diagnose faults quickly can help to eliminate faults and play an important role in ensuring the normal operation of power system [5]. Under the influence of some factors, if there is a fault, it is difficult to locate the fault effectively. Therefore, it is necessary to improve the fault location method of high-voltage overhead transmission lines effectively. Based on the research, the application level of fault location method is effectively improved. The research of fault location method based on microcomputer or microprocessor has also become one of the hot topics at home and abroad [6]. Instantaneous fault can restore power supply through reclosing, but the fault point is often the weak point, which needs to be found and dealt with as soon as possible, so as to avoid secondary fault endangering the safe and stable operation of power system [7]. When there is a permanent fault, it is necessary to find out the fault quickly and remove it in time. The time of removing the fault directly affects the power transmission guarantee of the transmission system and the safe operation of the power system. But the time of microcomputer fault location technology is not long, and it needs to be improved both in theory and in practical application [8].

2. Requirements for fault location of high-voltage overhead transmission lines

2.1 Fault location must be able to adapt to power systems of various structures and configurations

When fault location is carried out for high voltage overhead transmission lines, the methods that can be used are mainly single-ended method and double-ended method [9]. With the development of traveling wave transmission theory of transmission lines, people have done a lot of work in phase-mode transformation, parameter frequency variation and transient numerical calculation, which further deepens the understanding of traveling wave method and many related factors. Wave velocity is the main influencing factor in traveling wave ranging, and its calculation depends on earth resistivity and overhead line configuration. This kind of measuring method has many advantages, such as simple principle, low cost and free from traffic conditions, which has always been the focus of attention of scholars [10]. Single terminal fault location method is not limited by communication technology, and has the characteristics of simple theoretical analysis and clear physical meaning, and has been applied to a certain extent. The change of the impedance of the opposite end system is another important factor affecting these two algorithms, but there are relatively few literatures related to this aspect. It is not accurate to conclude that the iterative method of the impedance of the opposite end system deviates from the given value in a large range. However, the single terminal method also has some advantages in practical application. This method has relatively low requirements for the system at both ends of the lower line, and can carry out effective fault location in the weak links of the system.

In recent years, many researchers have introduced the achievements of related disciplines and put forward many novel ranging methods. Such as optimization method, Kalman filtering technology, pattern recognition technology, probability and statistical decision-making, fuzzy theory and optical fiber ranging, are currently in the research stage. This method mainly uses the voltage and current at both ends of the line to measure fault location, and reasonably takes accurate parameters as the basis, which makes the two-terminal method have certain convergence in ranging. In the case of ensuring the two terminal data synchronization, the reasonable application of GPS can effectively guarantee the accuracy of fault location results. In addition, the application of intelligent technology is also the main technology of transmission line fault diagnosis and elimination. For example, the use of intelligent technology can implement automatic alarm according to the actual situation of each circuit, and can realize the elimination of line fault in advance, which has important value and significance for reducing the occurrence of line fault.

2.2 Fault location must consider the appropriate line model

In the process of steady-state analysis of power system, it needs to be reasonably applied to the line model with parameter set. Under the condition that the system operation mode is determined and the line parameters are known, when a fault occurs somewhere on the line, the voltage and current at both ends of the line are functions of the fault distance. For overhead transmission lines, fault types mainly include single-phase to ground fault, phase to phase short circuit fault, two-phase short circuit to ground fault, etc. According to the function design, human-machine interface plug-in is divided into two parts: communication system and human-machine interface. As shown in Figure 1.

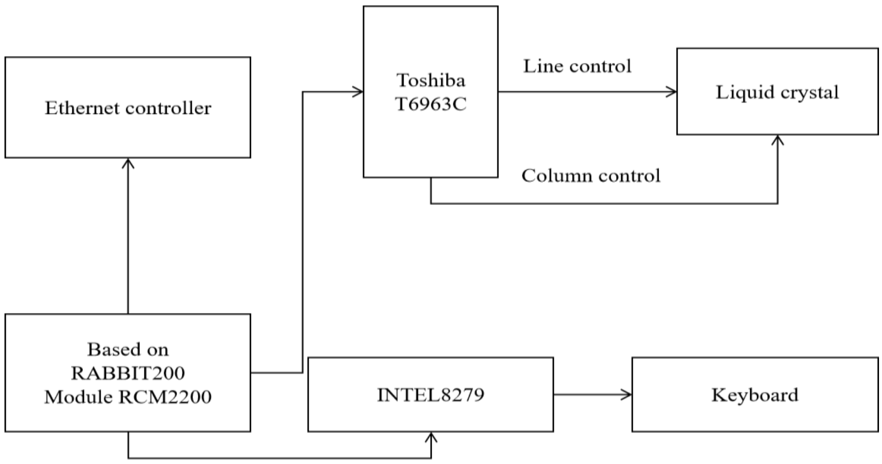

Figure 1. Human-machine interface plug-in structure

For a long time, the fault diagnosis mainly relies on manual inspection to find faults and eliminate them. The so-called time-domain ranging method for high-voltage overhead transmission lines is to use differential equations to solve directly in the time domain, which is used to describe the line model and achieve the purpose of fault location. When these algorithms are used for distance protection, misoperation and overrunning can be avoided by properly setting the action characteristics. All kinds of microprocessor-based protection devices developed according to these algorithms are widely used in power system and proved to be very reliable in practice. Therefore, fast and accurate fault location can save a lot of manpower and material resources, and reduce the labor intensity of the electrician. In the process of fault location, we need to be able to fully consider the line length requirements of various line models.

3. Specific fault location methods for high-voltage overhead transmission lines

3.1 Single-ended ranging

In the relay protection information system, two-terminal ranging is the preferred method of fault location, while single-terminal ranging is only an alternative scheme when two-terminal ranging conditions are not available. There are 10 simple fault types of high voltage overhead lines. In order not to lose generality. This paper introduces the fault location algorithm of overhead transmission line by taking single-phase grounding fault of dual power supply as an example. As shown in Figure 2. Figure 3 is the lumped parameter equivalent circuit corresponding to figure 2.

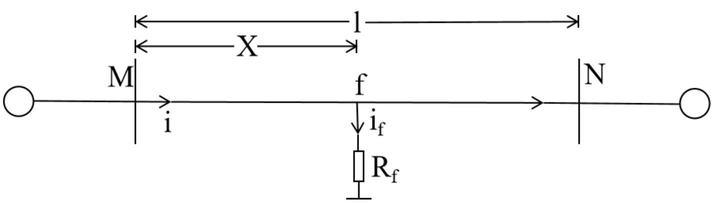

Figure 2. Dual power supply single circuit

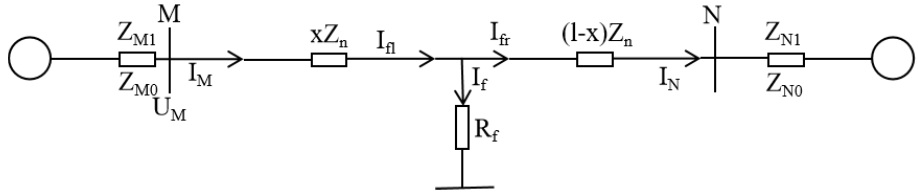

Figure 3. The lumped parameter equivalent circuit corresponding to Figure 2

$$U_M = (I_M + KI_{M0})^{\cdot} xZ_{l1} + 3R_f I_{f0} \quad (1)$$

$$I_{f0} = \frac{I_{M0}}{D_{A0}} \quad (2)$$

$$I_{f0} = \frac{\Delta I_{M1}}{D_{Al}} = \frac{I_{Mf}}{D_{Al}} \quad (3)$$

Type of R_f for fault transition resistance. $K = \frac{Z_{l0}-Z_{l1}}{Z_{l1}}$ is zero-sequence current compensation coefficient. I_{f0} is the zero sequence component of fault branch current, which is an unmeasurable unknown quantity. I_{M1}, ΔI_{M1}, $I_{M\theta}$, and $I_{Mf} = \frac{3}{2}(\Delta I_M - \Delta I_{M0})$ are all known quantities. $D_{A0} = \frac{(l-x)Z_{l0}+Z_{N0}}{Z_{l0}+Z_{M0}+Z_{N\theta}}$ and $D_{A1} = \frac{(l-x)Z_{l1}+Z_{N1}}{Z_{l1}+Z_{M1}+Z_{N1}}$ are the zero-sequence and positive-sequence current distribution coefficients respectively, and both are related to the impedance of the opposite end system.

In addition, it belongs to the time domain test method of HVDC transmission line to calculate the voltage distribution directly from both ends by using the electric power and current distribution, so as to locate the fault point. The single side voltage and current sampling time-domain ranging method of high-voltage transmission line is to use inductance, capacitance and resistance as the identified parameters, and calculate the voltage distribution along the line with the electrical quantities at both ends of the line. The fault distance is calculated and analyzed. The impedance of the opposite system is restricted by the system operation mode and load. The operation mode of the system changes between the maximum and minimum operation modes, and the load changes at the peak, valley and waist every hour, while the time of failure is uncertain. One of single-end distance measurement by impedance method. The impedance value from the short-circuit point to one side of the line is calculated, and the fault point position can be obtained by dividing this impedance value by the line impedance per unit length.

In the research of single-ended fault location algorithm, people often use the assumption that the fault branch current is in phase with a known current at the measuring end to eliminate the opposite end in the location equation. This assumption is not true for the whole line, so various ranging algorithms that depend on the parameters of the opposite end are gradually developed. When only using the voltage and current value of one side of the line to carry out the positioning, because the transition resistance is not zero and the number of positioning equations is less than the number of unknowns, this algorithm can not overcome the influence of the transition resistance in theory. Therefore, the single ended method needs to calculate the fault location on the basis of some approximate treatment. Based on asynchronous multi terminal fault location, the requirement of data synchronization is not as strict as synchronous fault location, but it also has higher requirements for hardware system.

3.2 Double-ended ranging

When a line is set, the voltages at both ends are expressed by m and n, and the boundary condition is mainly current. According to the corresponding formula, the specific line voltage equation can be enumerated. The ratio of zero-sequence current effective values at both ends is used to determine the position of single-phase grounding fault, but this method ignores the influence of distributed capacitance, and zero-sequence current distribution curves under several operation modes must be made in advance. The ranging results are related to the operation mode. For example, the application of artificial neural network technology can make use of the voltage and current components of the next path as neural network inputs, and can realize the judgment of fault location and the diagnosis of fault types. The time domain fault location algorithm of HVDC transmission line is to calculate the voltage distribution from both ends by using the voltage and electric flow at both ends, and to locate the fault according to the voltage distribution along the line is equal at the fault point. In this sense, only two terminal or multi terminal fault location method can eliminate the influence of fault transition resistance. Even if the data at both ends of M and N can not be synchronized, it will not interfere with the line amplitude, which can effectively ensure that the f amplitude is in a fixed state.

4. Conclusions

With the vigorous development of industrialization, electric energy is widely used. High-voltage overhead transmission lines are widely used as the main power supply lines. Although high-voltage overhead transmission lines have many shortcomings, with the development of society and the deepening of research, with the gradual improvement of fault location methods. High-voltage overhead transmission lines will be optimized, and its application scope will be wider. Because the single-ended ranging algorithm can't guarantee that there is no ranging error in principle, and the traveling wave rule is limited in its application due to the uncertainty of wave velocity and dead zone of ranging. Combined with the actual situation, this paper analyzes the fault location method of overhead transmission line, and puts forward the main factors causing the fault of overhead transmission line. On the basis of inheriting a large number of previous research results, this paper deeply studies the single terminal ranging of double power single circuit line and double terminal ranging of double power single circuit line and double circuit line. In order to improve the accuracy of fault location, the online estimation method of line parameters should be studied in the future. Hardware: efforts to develop a complete set of devices, so that it is easy to combine with the algorithm, and adapt to the requirements of the power field.

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