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Summary of Research on Protection of Double Circuit Lines on the Same Tower

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Abstract

The main protections of current double-circuit lines on the same tower are described, and the protection contents of power frequency and transients are summarized. The protection of double-circuit lines on the same pole is introduced through fault analysis, fault identification and fault phase selection based on power frequency quantities, traveling wave research and analysis and fault identification based on transient quantities, and the application of machine learning in fault identification will be introduced. Finally, the current situation will be summarized. The characteristics of the protection of double-circuit lines on the same pole and the problems that will be encountered in practice, the future research direction is drawn, and the future development direction is prospected.

Keywords

Double-circuit Lines on the Same Tower; Power Frequency; Transient State; Machine Learning; Research and Prospect.

1. Introduction

At present, my country's land resources are relatively scarce, and the cost of transmission lines is already very high, and the demand for electricity is increasing day by day. Double-circuit lines on the same pole can improve transmission capacity within limited land resources, and have been widely used. When a fault occurs on the transmission line, the correct phase and location of the fault are selected correctly, and can be cleared immediately, which is of great significance for reducing the loss of the fault and being able to quickly restore the normal power supply[1]. There are about 120 types of faults for double-circuit lines on the same pole, 22 of which are single-circuit faults, and 98 types of cross-line faults. Although cross-line failures account for a very large proportion of total failures, their failures account for less than 3% of total failures. However, if a line has a cross-line fault, its harm is greater than that of a single-line fault, and it may cause the collapse of the power system. Therefore, both protection issues must be considered when studying faults, and accurate electrical quantity calculations and faster line protection actions are required [2-4].

The double-circuit transmission line on the same pole has two loops and six lines, the distance between the double-circuit lines is relatively close, and the operation modes are also more diversified. This makes the fault types of the double-circuit line more complicated and the fault transient characteristics are more diverse, which leads to Conventional protection methods and setting calculation methods are difficult to directly apply, so the protection effect is not obvious. As it is increasingly used today, it is necessary to further study and summarize the protection device program and the subsequent operation conditions, so that the operation level is well improved and the maintenance of the operation of the power grid will be more realistic. The fault characteristics of

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double-circuit lines on the same pole are quite different from those of traditional single-circuit lines, and when the protection methods of traditional lines are applied to double-circuit lines on the same pole, there will be misjudgments or unrecognized faults, so it needs to be more comprehensive and Accurately study fault protection schemes [5-6].

2. Research on power frequency protection for double circuit lines on the same tower

At present, there are many methods of relay protection for double-circuit lines on the same pole, which can be roughly divided into the following categories: split-phase (split) current longitudinal differential protection, longitudinal distance (direction) protection, transverse differential protection, longitudinal zero-sequence protection and Protection based on six-sequence components [5]. In the double-circuit line protection on the same pole, the protection of the power frequency quantity is more robust than the transient quantity protection, and it can distinguish faults and disturbances. Therefore, it has been widely used in the protection of double-circuit lines on the same pole in recent years. The protection of power frequency quantity is mainly divided into fault analysis, fault identification and fault phase selection.

2.1 Fault analysis of power frequency quantity

The double-circuit line on the same pole is quite different from the traditional single-circuit transmission line, so the calculation model needs to be simplified, so that the calculation speed of the fault electrical quantity is improved, and the recognition accuracy is also significantly improved.

In the double-circuit line on the same pole, because the line distance is relatively short, there will be the influence of the mutual inductance between the lines and the mutual inductance between the phases. The protection that is often used in double-circuit lines on the same pole is the cross-differential protection. In [7], the cross-differential protection for the six-sequence fault component is proposed. The phase fault component is decomposed into six-sequence fault components, so that it can be eliminated. Mutual inductance between lines and phases, fault decoupling can be realized. This method will not be affected by some factors, such as the location of the fault point and the phase angle difference between the power supplies on both sides, and it can effectively improve the reliability of the protection. Literature [8] has the same method to study the multi-circuit lines on the same tower, and also uses the six-sequence fault component method and the cross-differential protection to select the line components. Literature [9] proposed a new six-phase fault analysis method, which divides the six-phase line system into two groups, and then performs the symmetry transformation; then decouples the mutually coupled sequence quantities, so that six mutually independent The order component.

The narrow line spacing double circuit line on the same pole is relatively common at present, because the distance between the lines is very short, so that the mutual inductance between the phases and the mutual inductance between the lines in a single circuit are relatively close. Literature [10] replaces the mutual inductance between the phases and the lines with the mutual inductances of the narrow line spacing double circuit lines with values close to each other, so that the short-circuit fault that occurs on the double-circuit line on the same pole can be simplified to an equivalent single-circuit line fault. , You can use the symmetrical component to solve. The six-order modulus is not used for analysis, which simplifies the calculation.

2.2 The principle of fault identification using power frequency quantities

At present, the fault identification of double circuit lines on the same pole at home and abroad is to determine the type of fault based on the construction criteria of phase current, voltage and wave impedance. Literature [11] proposed a double-circuit fault identification method based on voltage amplitude comparison, combined with the line distributed parameter model, using the electrical quantities measured at both ends of the line to calculate the distributed voltage of the transmission line in real time, faults outside the area, and inside the area. The difference in voltage distribution of

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faulty double-circuit lines is achieved by comparing the voltage amplitude between single-circuit phases and double-circuit lines to achieve rapid identification and phase selection reliability. In the literature [12], by analyzing the current value and impedance relationship of the positive and negative sequence fault components when general faults and cross-line faults occur in the line, a method for judging the double-circuit line on the same tower as a cross-line fault is proposed. The discriminant element. When a transmission line cross-line fault occurs, the positive and negative sequence fault impedance angles and impedance amplitudes are not equal, and the current amplitude of the positive sequence fault component is smaller than the negative sequence current amplitude. When a general fault occurs, these satisfying conditions are just the opposite. It can be a criterion for whether the system has a cross-line failure.

Literature [13] uses the wide-area measurement system to obtain the current and voltage at both ends of the double-circuit line on the same pole for six-sequence decomposition, uses the long-line equation of the transmission line with the same positive-sequence fault component in the six-sequence component to measure the fault distance, and then uses the electrical quantities at both ends The distance to the fault is used to obtain the current of each phase at the fault point with the help of the long-line equation, and the fault phase is judged as the amplitude characteristic of the phase current through the fault point. The literature [14] measures the wave impedance to identify the fault of the double-circuit transmission line on the same pole. First, the bus voltage and the current in the line are transformed into the initial traveling wave vector to obtain the initial traveling wave vector. According to the measured wave impedance, two concepts are given, Respectively, are sum wave impedance and difference wave impedance, introduce integrated sum wave impedance and comprehensive difference wave impedance. Theoretical calculations show that: when a fault occurs in the area, the integrated sum impedance is less than the integrated differential impedance; when a fault occurs outside the area, the integrated sum impedance is much larger than the integrated differential impedance. Introduce the ratio braking coefficient, take the integrated sum wave impedance as the braking quantity, and the integrated differential wave impedance as the action quantity, and establish the ratio braking protection criterion to identify the internal and external faults.

2.3 Principle of fault phase selection using power frequency quantity

In the traditional line parameter symmetrical double circuit line fault phase selection, the traditional six-sequence component method is usually used to eliminate the inter-line and inter-phase mutual inductance of current and voltage, and the six-sequence component method is used to decompose the current of the two conductors into positive sequence and negative sequence. Sequence, there is no mutual inductance between positive sequence and negative sequence loops [15].

Literature [16] started from the characteristics of cross-line faults on parallel double-circuit lines on the same tower, analyzed the existing problems of the existing phase selection components when they failed, and proposed a new fault phase selection scheme. Mainly after a fault occurs, the phase selection component first identifies the nature of the fault based on the characteristics of the zero sequence current, zero sequence voltage, and the relationship between the positive and negative sequence currents after the fault. Special phase selection is adopted for the cross-line fault of the double circuit line. Program. Literature [17] also judges the nature of the fault (cross-line or single-line fault) based on the characteristics of the zero-sequence current and zero-sequence voltage after the fault, and the relationship between the positive and negative sequence currents. Different selections are used for single-circuit faults and cross-line faults. Phase program.

When multiple faults occur, the fault phase needs to be correctly selected. Literature [18] proposed a comprehensive fault phase selection transmission scheme for double-circuit lines on the same tower. While ensuring the performance of phase selection for single-circuit faults, and at the same time realizing accurate phase selection for cross-line faults, a comprehensive fault phase selection scheme based on the sudden amount of phase current difference is proposed. The scheme has three types of fault phase selection. The first type is to improve the phase selection method according to the phase selection characteristics of the phase selection component under different fault types according to the

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sudden change of the phase current difference. For the second type, for single-circuit line and cross-line faults with the same name, the phase current difference mutation phase selection method is used directly or after equivalent; the third type is for non-same-name cross-line faults, using improved phase current difference mutation two-step phase selection In this way, different phase selection schemes are adaptively selected in this way, which not only guarantees the performance of single-circuit line phase selection, but also realizes accurate phase selection for cross-line faults. The literature [19] proposed a research on the phase selection method of the double circuit line on the same pole with asymmetric parameters, and proposed a new decoupling method for the faulty phase. In the first step, the three-phase is decomposed into positive sequence, negative sequence, and zero sequence components; the second step is to decouple the zero sequence components with coupling, and decompose them into the same direction component and the reverse component. This method solves the problem of zero-sequence mutual inductance of double-circuit lines with asymmetric parameters on the same pole. When the same line fault occurs, the amplitude and phase relationship between sequence components can be obtained through the fault boundary conditions. When faults occur on different lines, the current amplitudes of the positive sequence components of the two loops are different. When different types of faults occur on the same loop, the amplitudes of the six sequence current components have a corresponding relationship. When the same type of fault occurs in different phases, the phases of the six-sequence components will also be different.

3. Research on transient protection of double circuit lines on the same tower

With the continuous application of machine learning in handling faults and the continuous development of science and technology, signal processing technology has been greatly improved, and the application of transient protection in double-circuit lines on the same pole has also increased. Sexual research has also developed rapidly.

3.1 Research and Application of Traveling Wave Characteristics of Double-circuit Transmission Line on the Same Tower

Literature [20] analyzes the fault current traveling wave of double-circuit lines on the same tower, and performs theoretical calculations through the Peterson model for single-circuit line faults in the MN area of the double-circuit line on the same tower and the Peterson model for cross-line grounding faults of the same-name phase. It is concluded that when the internal single-circuit line fails, the phase of the current traveling wave on the same side of the line is almost opposite; when the same-name phase cross-line ground fault occurs, the phase of the current traveling wave on the same side of the line is almost the same, and the phase of the current traveling wave on the same side of the line is almost the same. The phase of the current traveling wave is almost the same; when the fault occurs outside the area, the phase of the current traveling wave on the same side of the two lines is almost the same, and the phase of the current traveling wave at both ends of the same line is almost opposite. A large number of simulation results show that the theoretical calculation is correct. Literature [21] proposed a new method of fault traveling wave selection and traveling wave detection for fault traveling wave selection and traveling wave detection. Due to the large difference in the propagation characteristics of the modes after the traditional phase-to-mode conversion, a new phase-to-mode conversion is proposed to solve this problem. Variational modal decomposition through parameter optimization is combined with Teager energy operator and applied to traveling wave detection. It has better detection effect in adaptive adjustment. By comparing with the detection results of wavelet transform modulus maximum and Hilbert-Huang transform, it is concluded that the variational modal decomposition + Teager energy operator has good superiority. After a large number of simulation results verify that the method is feasible and the ranging results are accurate.

3.2 Fault identification of double-circuit lines on the same tower using transients

At present, there are more and more transmission lines studying transient protection. Literature [22] obtains transient energy after wavelet transformation of the fault current components of each phase, and these transient energies constitute the basis for determining phase selection. Since the phase

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selection has the principle of equivalence, the fault phase can be preliminarily identified, and then the same-named phase line selection based on the magnitude of the transient energy can determine and identify the fault phase, thus forming a complete fault phase selection program.

Literature [23] studied the transient current component of the fault, installed the cross-differential protection of the current transient fault component at both ends of the double-circuit line, and then installed the current transformer at both ends to measure the current and compare it with the current transformer at both ends. The correlation coefficient is calculated for the transient fault component. When the correlation coefficient is greater than the set rated value, it can be concluded that the fault is an out-of-zone fault based on the previous criterion, and the protection will not act. If the correlation coefficient is less than the set rated value, it is an area fault, the protection will operate reliably, and the fault branch is determined by the square of the current sampling value.

4. Application of machine learning in fault identification

At present, artificial intelligence research is very popular, and artificial intelligence is used in fault phase selection and ranging. Literature [24] uses a convolutional neural network to study the method of fault judgment and fault phase selection within and outside the transmission line, using a CNN network structure of two softmax classifiers, and using a network structure to solve two non-independent classification problems at the same time. In simulation and actual fault test variables, this method can realize the classification of the two, and the sampling rate is relatively low, no parameter setting is required, and it is not affected by some factors of the system, and the result is more accurate and reliable.

Literature [25] proposed a method based on multi-resolution singular value decomposition and random forest area and outside fault identification, First, collect and read the initial traveling wave current data for phase-to-mode conversion, and then perform multi-discrimination singular value decomposition. The data within 0.2ms after the fault is selected to calculate the integral of the traveling wave current at each scale at both ends according to the formula, and the integral of the downward wave current at each scale at both ends is proposed as the feature vector, and the final recognition result is obtained through the random forest classifier. It is verified by simulation that this method can accurately identify faults under various working conditions.

5. Prospects for protection of double circuit lines on the same pole

The current research on the protection of power frequency quantities and transient quantities has been very mature, but there will be some problems to be solved:

(1) In the research of power frequency protection, we usually use the six-sequence component method for decoupling. This method is not very simple, and there will be insufficient accurate judgments when the same name cross-line fault occurs. Most double-circuit lines on the same pole with symmetrical line parameters use the six-sequence component method. When the line is asymmetry, you have to think about other methods for decoupling.

(2) The double-circuit line on the same pole uses more power frequency protection than transient protection. Although transient protection is faster and more accurate, it is not as robust as power frequency protection. The protection of transients in the research needs more in-depth study.

(3) Artificial intelligence research is hot today. In the future, the application of machine learning in the fault identification of double-circuit lines on the same pole will be more extensive. Using its advantages in fault phase selection, the accuracy of fault phase selection will be greatly improved.

Acknowledgments

On the basis of the predecessors, the double circuit line on the same pole is summarized, the advantages and disadvantages of various methods are analyzed, and on this basis, I need to further research on machine learning and transient fault phase selection.

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