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Research on Fault Diagnosis for T-type Transmission Line

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Abstract

According to the existing research results at home and abroad, the fault characteristics of the T-type connection line are different from the double-ended line and it will appear more and more in the power grid. The paper reviews the development status of T-type connection line fault diagnosis at home and abroad, and divides the way of fault diagnosis for T-type Transmission Line into traveling wave method and fault analysis method to sort out and summarize the technology, and reviews the diagnostic mechanism, characteristics and deficiencies of various fault diagnosis methods. Finally, the development direction is prospected to promote the further development of the research field.

Keywords

T-type transmission line,Fault analysis method for T-connection line, Traveling wave method for T-connected.

1. Introduction

The T-type connection line means that a line is indirectly from the line that Party A supplies to Party B, and supplies power to third-party C. With the development of the national economy, the demand for electricity shows a trend of continuous growth. Due to the limitation of power supply radius, corridors, etc., in order to save equipment investment and improve the use efficiency of the line, the T-type connection line more and more be used in the power system. However, at the same time, the line generally has the characteristics of high transmission power and heavy load. Once the line fails, it may cause a large-scale power outage. Therefore, when the T-type connection line fails, it is more important to perform fast and effective fault diagnosis. T-type Transmission Line model,see Fig. 1.

The principle of the traditional fault diagnosis is that the impedance method is basically the same as the principle of the impedance relay. The impedance of the circuit is calculated according to the measured voltage and current at the time of the fault, and the distance between the protection installation and the fault point is obtained according to the line length and the impedance. However, due to the complexity of the fault nature, the transition resistance, the incomplete symmetry of the line and the boosting current caused by the power supply and the draw current caused by other line, the traditional impedance method often has a large ranging error. But the fault analysis method and the traveling wave method perform much better.

The paper synthesizes the status quo of the T-type connection line at home and abroad, and comprehensively summarizes and summarizes the current status of T-type connection line fault diagnosis technology, analyzes the research difficulties in various aspects and makes recommendations. On the basis, it is expected to promote the further development of the research field.

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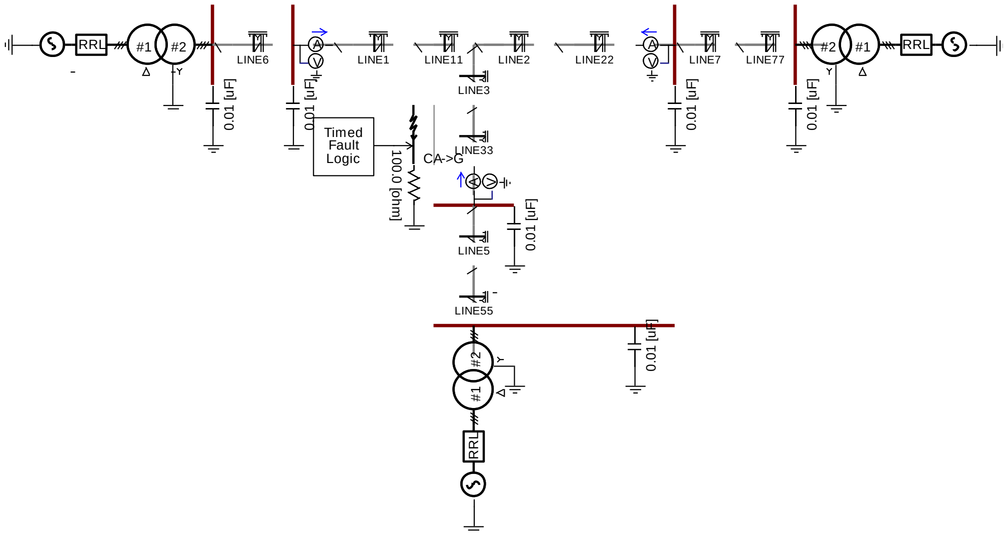

Fig. 1 T-type Transmission Line model

2. Fault analysis method for T-connection line

The method of directly using the wave equation to derive the electric quantity distribution along the line is the fault analysis method. It can generally be divided into one-sided electrical quantity method and two-side electric quantity method. By measuring the voltage and current at the point, we can get the voltage and current value at any point on the line, and combine the characteristics of the voltage and current at the fault point for fault diagnosis.

The one-sided electrical quantity method only uses the voltage and current amount on one side, and does not need to rely on the opposite side of the electrical quantity. However, due to the influence of the operating parameters on both sides, in order to calculate the accurate result, multiple iterations are required, and the calculation processing capability is put forward in the application. The two-side electric quantity method on both sides requires the voltage and current on both sides. According to the difference of the opposite side electrical quantity, it can be divided into two side current, one side voltage method and two side voltage and current methods. A T-connection line fault analysis method,see Fig. 2.

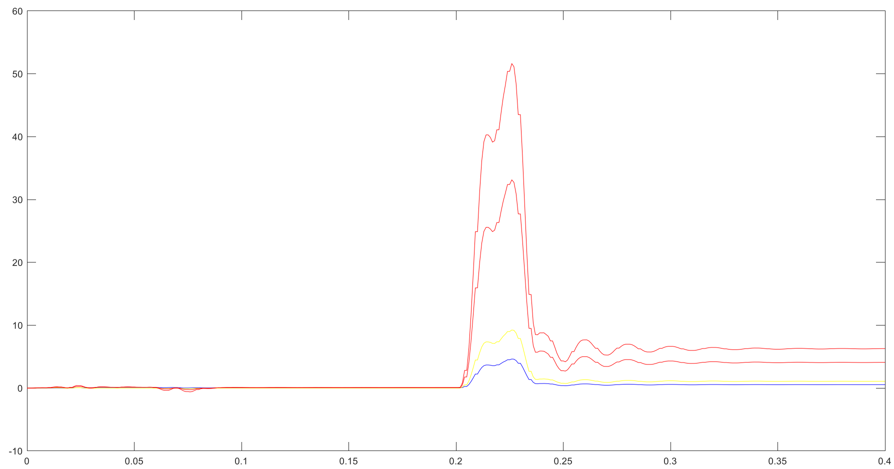

Fig. 2 A T-connection line fault analysis method

Literature [1] proposes an algorithm for accurate fault location for ultra-high voltage T-type connection line. The algorithm firstly determines the fault branch by using the positive sequence voltage and current of each terminal and the positive sequence parameter of the line, and then locates the fault branch according to the double-ended line. The algorithm establishes π-equivalent value model, which more realistically reflects line including the existence of distributed capacitance. The

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simulation results show that the algorithm has high precision and stability, and the positioning error generally does not exceed 0.5%.

In Literature [2], based on the lumped parameter line model, three different T-node voltages calculated by three-terminal electrical quantities are compared with each other, and the different branch are judged as faulty branches. Then, the voltage of the T node and the current injected into the faulty branch are obtained from the electrical quantity of the non-faulty branch. However, the literature ignores the influence of distributed capacitance which will cause large errors for long transmission lines. In literature [3], based on the distributed parameter line model, a new method for fault location of T-type connection line is proposed. The discrimination of the fault branch and the equivalent method of the 2-terminal line are the same as in the literature [2]. The literature [4-6] uses the differential equations in the time domain to diagnose fault, and the fault branch discrimination method is the same as the literature [2]. The literature [7-8] is based on the characteristics of the negative sequence equivalent circuit in the asymmetric fault of the power system to diagnose fault, and the fault branch discrimination method is the same as above.

In Literature [9], a new fault branch method is proposed. Firstly, it is assumed that another branch does not exist. The 3-terminal branch is regarded as the 2-terminal branch distance measurement. If the measured fault distance is larger than the distance of the actual T node, the fault is in the opposite branch, if it is smaller than the distance of the actual T node, the fault is on the side branch, and if it is equal, the fault is in the third branch. However, when the fault occurs near the T-node or occurs on the third branch, due to the influence of the transient process, the real part of the measured distance swings around the T node. Therefore, the method cannot correctly judge the fault near the T node.

In Literature [10], the concentrated parameter line model of distributed capacitance is considered. The relationship between the ratio of the fundamental wave component of the positive sequence voltage and the distance factor p is used to obtain the curve. The comparison curve can be used for single return fault location. The algorithm is not affected by fault type, transition resistance and pre-fault conditions. It does not need to synchronize data sampling at both ends, but does not give a location scheme for different T wiring. Literature [11] uses the voltage variation and impedance relationship of double-end synchronous measurement for fault location. The algorithm has small calculation, fast speed and good practicability, but does not consider the coupling problem of parallel double-circuit line.

Literature [12] introduced a fault diagnosis method based on fault analysis method, which can adapt to a variety of operating modes and is simple to calculate. According to the three-side voltage, the three-side current and line positive sequence impedance parameters of the T-connection line, it calculates the T-nod voltage on each side, identifies the faulty branch according to the calculated amplitude of the T-contact voltage, and then uses the T-nod and the faulty branch achieves double-ended fault location.

In literature [13], a new T-type connection line fault location method is proposed by using the pure resistance property of the transition impedance. The method breaks the traditional mode of judging the fault branch and then fault location, that is, the distance can be measured without prior identification of the fault branch. The method has no dead zone of location, and the accuracy of location is not affected by the transition resistance and the type of fault. It overcomes the shortcomings of the traditional method in the vicinity of the T node, but on the non-faulty branch, the values obtaining from the location function are greater than zero without a theoretical basis, and thus the location task cannot be completed. In literature [14], the existing T-type high-voltage line fault location method has the problem of location dead zone in the case of high-resistance short-circuit fault near the T-node. A fault fast-location method suitable for T-type high-voltage lines is proposed. According to the analysis, the phase of the location function will be abruptly changed before and after the fault branch fault point, and the phase of the location function will not be abrupt on the normal branch. Therefore, the phase jump point of the location function is the fault point feature used for fault location. According to the analysis, the phase of the ranging function will be abruptly changed

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before and after the fault branch fault point, and the phase of the ranging function will not be abrupt on the normal branch. Therefore, the phase jump point of the ranging function can be used as the fault point that is used for fault location. In literature [15], the paper provides the necessary guarantee for quickly finding the fault point and shortening the troubleshooting time. It breaks through the traditional T-type line fault location thinking that treats the fault point as an unknown condition, and proposes a T-type line using the matching idea. New fault location algorithm. The method constructs a new location function based on the idea that the fault location is treated as a known condition and the reference point is matched. The positioning is performed according to the feature that the amplitude of the location function is minimized when the reference point taken on the faulty branch matches the fault point. The method breaks the traditional mode of judging the faulty branch and then fault location, and can measure the distance without prior discriminating the faulty branch. The method has no dead zone of location, which better overcomes the shortcomings of the traditional method in the vicinity of the T node, and has no pseudo roots. It has good applicability to nonlinear resistance faults, and requires a small amount of computation. It can effectively overcome the contradiction between the location accuracy and the location speed of the traditional method. However, in the literature [14-15], the distance measurement needs to be searched on each branch, so the algorithm has insufficient positioning speed and cannot realize online monitoring.

In summary, the T-type connection line fault analysis method directly uses the wave equation to derive the electrical quantity distribution along the line to diagnose the fault by measuring the voltage and current at the point, and combining with the characteristics of the voltage and current at the fault point. At present, T-type connection line fault diagnosis mainly solves problems such as diagnosis inaccuracy, signal coupling, T-node fault location errors through Building new models, using three-terminal equivalent to double-end way, directly using three-terminal data way, decoupling electrical signals, constructing equations and constructing location function.

3. Traveling wave method for T-connected line

The D'Alembert formula of the wave equation shows that the voltage and current are formed by the superposition of the forward and backward waves. The traveling wave is a physical quantity related to both time and distance, and the propagation distance and propagation time are constrained by the wave velocity. Therefore, the fixed observation point can estimate the propagation distance by the time information of the arrival of the traveling wave, which is the basic principle of the traveling wave method.

The traveling wave method is divided into A, B, C, D, E and F types. Among them, A, C, E, and F are based single-ended principles, while B and D are based double-ended. The A-type traveling wave method performs fault diagnosis by the reflected wave of the initial traveling wave at the fault point. The B-type traveling wave method diagnoses the fault by the initial traveling wave moment generated during the fault and the moment when the other end of the line returns to the initial traveling wave surge. The C-type traveling wave method injects a high-voltage high-frequency pulse or a high-voltage DC pulse into the measurement point at one end of the fault line, and then feels the initial surge of the fault, so that the fault diagnosis purpose can be achieved. The D-type traveling wave method realizes fault diagnosis by carrier synchronization. The E-type traveling wave method uses the single-ended principle of the faulty line reclosing transient traveling wave to perform fault diagnosis. E-type traveling wave method uses faulty line reclosing to generate transient traveling wave single-ended principle for fault diagnosis. The F-type traveling wave method uses the principle that the fault line is opened to generate a transient traveling wave for fault diagnosis. A Traveling wave method for T-connected line, see Fig. 3.

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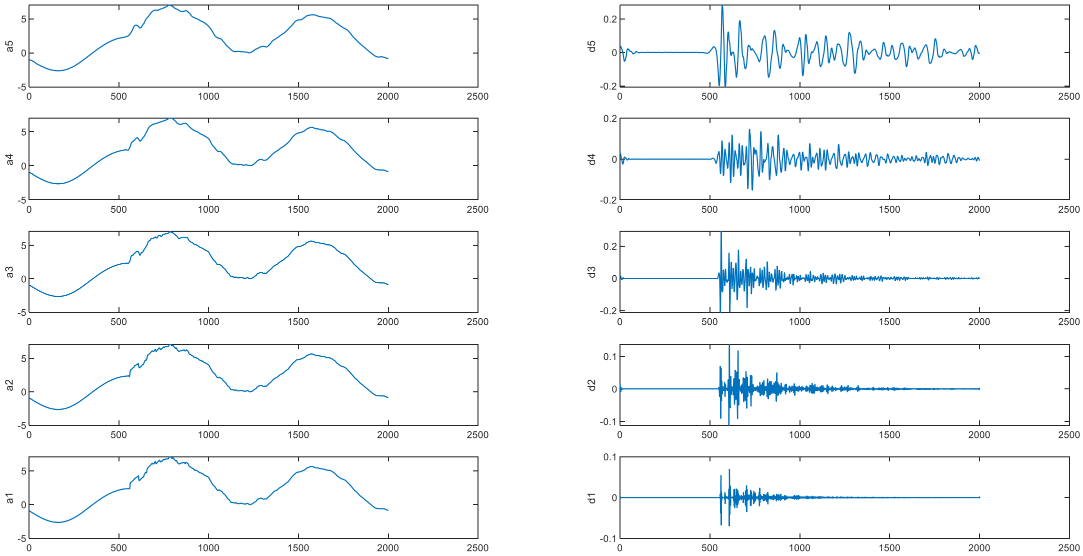

Fig. 3 A Traveling wave method for T-connected line

In literature [16], the traveling wave fault characteristics of T-type transmission lines with series compensation devices, mutual coupling lines and different grounding resistances are analyzed, and the initial traveling wave, fault point and T-node deflection of the fault are measured, which is used for fault location. Literature [17] proposes a criterion for fault branch discrimination using traveling waves. It does not consider the influence of actual error on branch discrimination, and performs location only by two of the three measuring ends.

In literature [18], based on the distributed parameter line model, a new method for fault location of three-terminal system is proposed. Literature [1] proposes an algorithm for accurate fault location for ultra-high voltage T-type connection line. The algorithm uses the positive sequence voltage and current of each terminal and the positive sequence parameters of the line to establish a quadratic equation group for fault diagnosis. Firstly, the fault branch is determined, and then the fault branch perform fault location according to the double-ended line. The algorithm establishes the line model with π-equivalent value line model, which more realistically reflects the existence of distributed capacitance. In literature [3], the single-ended data transmission line fault location algorithm is more difficult to solve the fault location problem of multi-terminal systems. In practice, multi-terminal data is generally used for location. The paper uses the data of the second half-cycle after the fault to establish the time-domain differential equation. All the solutions are performed in the abc coordinates. The fault location does not need to judge the fault type, and the least squares technique is used to theoretically guarantee the location algorithm has high ranging accuracy. The traveling wave location method based on wavelet transform proposed in literature [17] needs to estimate the wave velocity, and the location may produce large errors.

Literature [22] proposed a method for judging faulty branches by using wavelet energy, but for T-type lines, fault location using reflected waves is difficult in practical applications. In Literature [17], the fault distance calculated by using the data at either end is compared with the known line length to judge the fault branch, but the wave speed needs to be estimated, which may cause a large ranging error.

In literature [17], the fault branch discrimination is performed only by any two of the three measurement terminals. Literature [16] proposed using wavelet energy to judge the fault branch, which does not consider the influence of actual error on branch discrimination. In literature [19], the idea of comprehensively utilizing the three-terminal data of the T-type line for fault location is proposed. When a fault occur in the vicinity of the T-node, there is a dead zone. In literature [20], a new T-type connection line traveling wave fault location algorithm is proposed for the existing T-type connection line traveling wave fault location algorithm whose location results are susceptible to

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traveling wave velocity. According to the principle that the downlink wave velocity is equal under the same condition, when the length of line and the time of the initial traveling wave of the fault current reach the three ends of the line are known, the precise value of the traveling wave velocity is not required to participate in the judgment and calculation. It excludes the influence of the fault branch judgment and the location accuracy in some cases, and there is no dead zone near the T node, but its location formula is only applicable to some cases.

Literature [21] considers the determination of the wave velocity of the traveling wave and the calibration of the arrival time of the wave head of the fault traveling wave is the main factor affecting the accuracy of the traveling wave ranging. Literature [22] considers that the series capacitor and its nonlinear protection device bring difficulties to the fault location of the series compensation line. However, the single-ended location method mentioned in the literature [21] and the literature [22] does not solve the problem of identifying the faulty branch when it is applied to a multi-terminal line. Literature [23] uses single-ended power frequency fault information or traveling wave fault information to achieve fault location in various situations. However, it only identifies the faulty branch and the fault location based on the deflection of the fault traveling wave which is difficult to identify the wave head of. Literature [24] uses the three-terminal fault traveling wave measurement data of T-type high-voltage transmission line, and uses the improved method of cross-correlation function--the unit impulse response method to obtain the signal delay of both ends. However, when the algorithm mentioned in Reference [24] is faulty near the T point, it is easy to cause the faulty branch to discriminate and the fault distance calculation error. In literature [27], the existing T-type traveling wave fault location algorithm is vulnerable to traveling wave velocity, and a new T-type traveling wave fault location algorithm is proposed, but it is only applicable to some situation. In literature [25], the phase current is firstly converted into independent mode current by Clarke transform, and then the static current transform (SWT) is applied to the mode current. Finally, the calibration of each line wave arrival at each bus end is realized. However, when the fault occur near the T node, the deflection of the fault traveling wave will make the identification of the faulty branch difficult.

In summary, The T-type traveling wave method diagnoses faults by the idea that the traveling waves are time-dependent and distance-dependent physical quantities and the traveling wave is formed by superposition of a forward wave and a reverse wave. At present, the traveling wave fault diagnosis mainly solves the problem such on inaccurate diagnosis, the impact of wave speed on diagnosis, wave continuous weakening during propagation, electrical signal coupling, and unobservable traveling wave signal though building a better model, using three-terminal equivalent to double-ended, ,directly using three-terminal data, decoupling electrical signals, building equations and selecting traveling wave types.

4. Prospective to the future

With the economic development, T-type transmission lines are used more and more widely in the power grid. However, at the same time, the line generally has the characteristics of high transmission power and heavy load. Once the line fails, it may cause a large-scale power outage. Therefore, the research on T-type connection line fault location algorithm has attracted more and more attention. The paper synthesizes several domestic and foreign literatures and learns that the fault analysis method often uses a more accurate circuit model to simulate the operation of the line ,and decouple the observed data into independent quantities that do not interfere with each other, and make the most of the data, such as using three-terminal data calculations, constructing equations and so on ,and pay more and more attention to constructing the ranging function using the wave equation to calculate the phase change for fault diagnosis. At the same time ,The traveling wave method uses a more accurate circuit model, and decouples the observed data, and makes full use of the data like the fault analysis method ,and construct a formula without wave velocity, which is expected to reduce the impact of wave velocity and Use the data of the wave head of the initial traveling wave as much as possible.

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The above may be the future direction of development, and it is expected to play a role in promoting the direction.

5. Conclusion

First of all, the paper introduces the concept of T-type line, and explains its importance in grid operation and the shortcomings of traditional impedance method in T-type connection line fault diagnosis. Then the T-type connection line fault diagnosis method is divided into fault analysis method and traveling wave method to introduce its principle and classification. Finally, several domestic and international articles are reviewed, and the possible future development directions are obtained. It is expected to be able to promote the field.

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