Research on Fault Diagnosis for T-type Transmission Line

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Abstract

This paper analyzes the status quo of fault diagnosis for T-type transmission line, divides the fault diagnosis algorithm of T-type transmission line into traveling wave algorithm and fault analysis algorithm and points out the characteristics and problems of the traveling wave algorithm and the fault analysis algorithm for T-type transmission line. Secondly, it introduces the development status of the microprocessor relay protection device used in the fault diagnosis for the transmission line. Finally, the development trend of fault diagnosis of T-type transmission line is forecasted.

Keywords

T-type transmission line, Fault diagnosis algorithm, Microcomputer relay protection device.

1. Introduction

In recent years, with the rapid development of China's economy, electricity demand has continued to grow. Due to the limitation of factors such as the power supply radius and the power supply corridor, T-type transmission line are increasingly appearing in the grid[1]. Because transmission lines are often connected to large power grids and large systems, if it cannot be quickly identified and removed when a failure occurs, it will affect the normal operation of the power system until the breakdown of the system is caused and even a large-scale blackout occurs. Because of the special nature of the T-type transmission line, the three transmission lines affect each other's electrical quantity, and the existence of T node causes additional factors for fault diagnosis. For example, T node will generate extra reflection and reflection of traveling wave, which makes T-type transmission line diagnosis difficult. Therefore, it is more and more important to research on fault diagnosis for T-type Transmission Line. T-type transmission line is shown in Fig. 1.

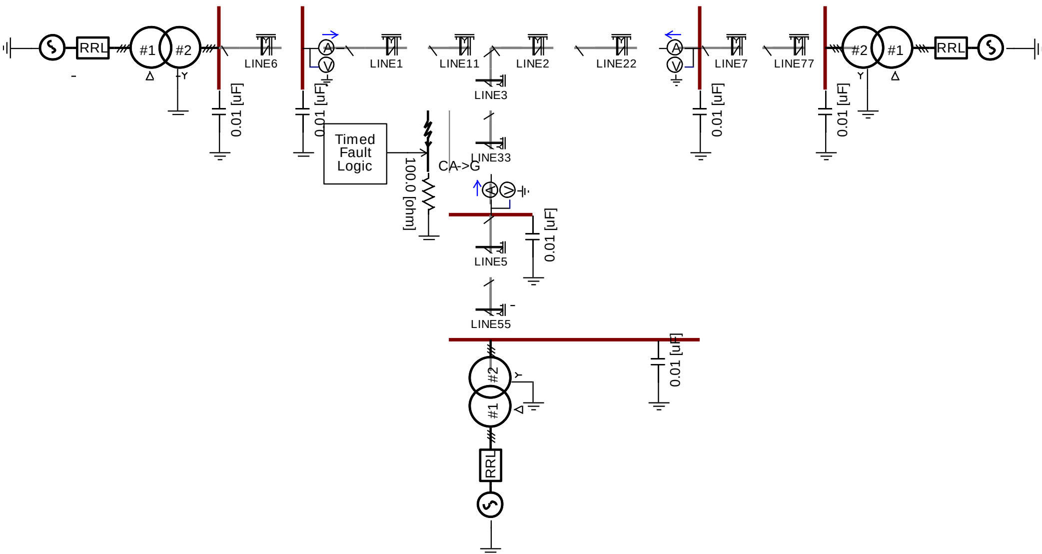

Fig 1. T-type transmission line

In this paper, many fault diagnosis algorithms for T-type transmission line proposed by scholars at home and abroad is studied and classified into traveling wave algorithm and fault analysis algorithm, the characteristics and problems of both of whom are pointed out. Then, the microcomputer relay protection device used in fault diagnosis of transmission lines was introduced. Finally, the development trend of fault diagnosis for T-type transmission line is forecasted based on the research in recent years.

2. Fault Diagnosis Algorithm for T-type Transmission Line

The fault diagnosis algorithm for T-type transmission line determines whether the fault occurs in the area or outside and which branch fails through the voltage of the three terminals of the transmission line, the current of the three terminals, the time of arrival at the three terminals, the velocity of the wave, and the parameters of the line. Compared with the two-terminal transmission line[2], the fault diagnosis algorithm for T-type transmission line is not mature enough. But the physical nature of the two is the same, which makes some of two-terminal transmission line fault diagnosis algorithm can also be used for T-type transmission line. However, the structural differences of the two have resulted in their Unique fault diagnosis algorithms. At present, the T-type fault algorithm can be divided into traveling wave algorithm and fault analysis algorithm. Traveling wave algorithm is less used due to equipment cost, implementation technology and so on. Fault analysis is easy to implement and is now widely adopted.

2.1 The Fault Analysis Algorithm for T-type Transmission Line

Fault analysis algorithm is defined as a fault diagnosis algorithm using power frequency voltage and current measured at the time of failure. According to the classification of measurement information, the fault analysis algorithm can be divided into single-terminal algorithm and double- terminal algorithm [3]. The single-terminal algorithm can be used to diagnose faults based on electrical parameters of only one terminal of the transmission line. The double-terminal algorithm is used for fault diagnosis according to the parameters measured at each terminal of the transmission lines. The fault diagnosis algorithm for two-terminal transmission line can be either the single-terminal algorithm or the double-terminal algorithm. For T-type transmission line, because the parameters measured by single-ended algorithms are often insufficient, double-end algorithms are often used. The fault analysis algorithm has low requirements on the sampling frequency and is reliable and easy to identify. But it is susceptible to factors such as capacitive current, load current, transition resistance, and CT saturation, and there may be outgoing load current when an internal fault occurs on a T-type transmission line. Normal current and fault current in Fault analysis algorithm are shown in Fig. 2.

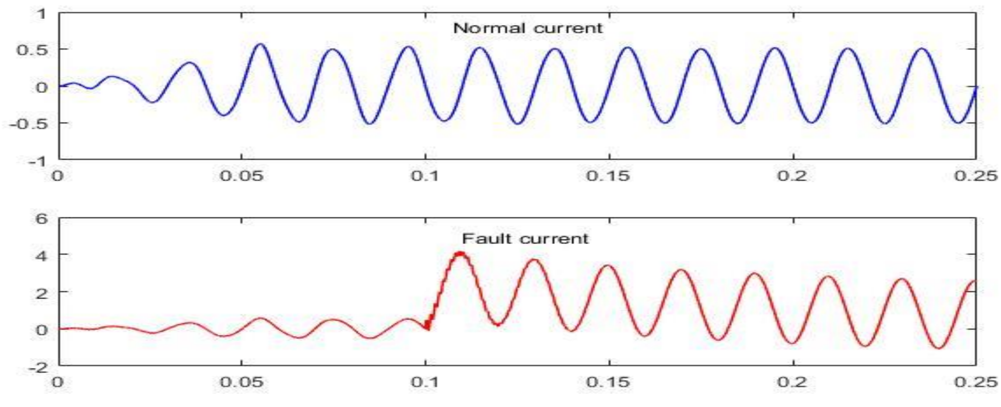

Fig 2. Normal current and fault current

The literature [4] calculates the voltage from each terminal to the T node through the three-terminal voltage and current, and then the values are subtracted each other and taken the modulus of. When the transmission line runs normally or the T node fails, each module value is approximately equal to 0. When an internal fault occurs (except T nodes), the branch with the larger modulus value is the fault branch. Literature [6] was improved on the basis of [4]. The paper used the positive and negative sequence voltages and currents of the T-type transmission line to calculate the T-node voltage. Literature [7] proposed an adaptive fault diagnosis algorithm. The fault diagnosis algorithm calculates the transmission line parameters in real time by measuring the electrical quantities of two different phase angles, and then uses the algorithm being similar to the literature [4] to perform fault diagnosis. The algorithm solves the problem of inconsistency between actual line parameters and parameters provided by the power supply department.

Literature [8] proposed a new algorithm of fault diagnosis for T-type transmission line by using node voltage algorithm. The fault diagnosis algorithm uses the admittance matrix to transform the change of the voltage of each node and the line current into the change of the transmission line structure when a fault occurs. The accuracy of this algorithm is not influenced by the saturation of the current transformer at the time of fault and the error rate is controlled within 1%.

Literature [9] proposed that when an internal fault occurs, each fault current is in the same direction. When the fault occurs outside, the fault current near the fault terminal is in the opposite direction to the fault current at the other two terminals. For the CT saturation problem, the fault can be judged and identified based on the sudden increase of the modulus of the current vector sum and the sudden decrease of the sum of the current vector modulus. Literature [10] based on the literature [9], Literature [10] let its directional characteristics are represented by $\cos\theta$. When an internal fault occurs, $\cos\theta > 0$. The larger the braking coefficient is, the smaller the braking amount is. When an external fault occurs, $\cos\theta < 0$. The larger the braking coefficient is, the larger the braking value is. (θ Represents the angle between the maximum value of the three-terminal current vector of the transmission line $I_{\max}$ and the sum of the other two terminal current vectors I_{Σ}). The algorithm makes the braking coefficient can be infinitely large. Based on the literature [9], the literature [11] expresses the directional characteristic by the braking coefficient $|\tan(\theta/2)|$. When an internal fault occurs, $|\tan(\theta/2)|$ approaches zero and relay protection device does work. When an external fault occurs, $|\tan(\theta/2)|$ tends to ∞ and Relay protection device does not work. In this paper, according to the principle that the phase angle small change when CT is saturated, the original algorithm is changed to the module of the vectors sum greater than the product of $|\tan(\theta/2)|$ times the sum of the vector, and the changed algorithm have a reliable operation when CT is saturated.

The literature [12] proposes a new fault diagnosis algorithm based on integrated impedance. When an external fault occurs, the integrated impedance is the capacitive impedance of the transmission line and have a large module value. When an internal fault occurs, the integrated impedance is the sum of the impedance of the transmission line and the impedance of the power supply and have a smaller module value. The value of the module can be used to determine whether the fault is internal or external.

Literature [13] proposed a new fault diagnosis algorithm for T-type high voltage transmission line based on fast fault branch identification. It uses a positive sequence voltage to derive a diagnostic function. When a fault occurs, the phase of the diagnostic functions at both ends of the fault line is approximately inverted. The diagnostic function of the healthy transmission line is approximately in the same phase, so that this feature can be used to achieve the purpose of fault diagnosis. This algorithm can overcome the shortcomings of traditional algorithms that cannot reliably identify faults near T nodes.

The literature [14] takes its advantages from the main criteria of the traditional algorithms $|I_{\max} + I_{\Sigma}| > K_1 |I_{\max} - I_{\Sigma}|$ and $|I_{\max}| + K_2 |I_{\Sigma}| \cos\theta > 0$ to form its main criterion. The reliability of the first algorithm is better than that of the second algorithm. The sensitivity of the second algorithm is better than the first algorithm.

In summary, Fault analysis algorithm uses voltage, current, etc. to diagnose faults. The algorithm which is reliable and practical has been widely used in the grid. However, there are still many problems that need to be solved. For example, the effect of transmission line parameters on the algorithm and CT saturation.

2.2 The Traveling Wave Algorithm for T-type Transmission Line

The research of traveling wave algorithm began in the early 1940s [15]. It is based on traveling wave transmission theory to realize fault diagnosis. Traveling wave algorithm can be divided into three categories according to its principle: traveling wave direction diagnosis, travel wave distance diagnosis algorithm and traveling wave differential diagnosis. The traveling wave direction diagnosis is a fault diagnosis consisting of the polarity and direction of traveling wave. The traveling wave distance diagnosis algorithm is based on the traveling wave reflection principle to calculate the fault distance and achieve the purpose of fault diagnosis. Traveling wave differential diagnosis is based on the difference of directional traveling wave on each side of the line to diagnosis fault. These three types of algorithms apply to not only two-terminal transmission line and T-type transmission line. Traveling wave algorithm fault diagnosis is not affected by factors such as capacitance current, system parameters, operation mode, line asymmetry and transformer change error, and its accuracy is higher than that of fault analysis algorithm. However, there are difficulties for traveling wave in identifying the wave head, high sampling frequency, dispersion in the traveling wave propagation process, special equipment required, and large capital investment. Compared with the two-terminal line, the traveling wave algorithm will generate extra refraction and reflection due to the presence of T-nodes, which makes it more difficult to determine the fault occurrence area, identify the fault branch and the traveling wave head. Traveling wave is shown in in Fig. 3.

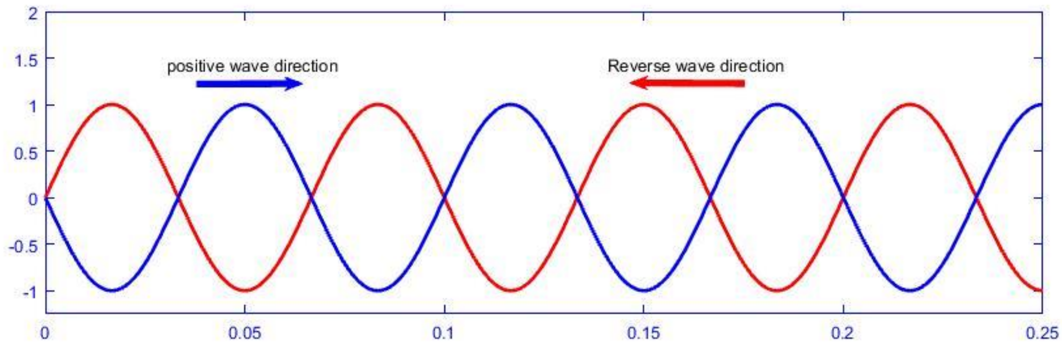

Fig 3. Traveling wave

The literature [17] proposed a differential diagnosis algorithm with slightly proportional braking characteristics. It uses the difference function composed of the directional currents at each end to diagnosis fault. The algorithm can maintain high sensitivity in a high impedance fault.

Literature [18] proposed a fault diagnosis algorithm for T-type transmission line based on the D-type traveling wave principle. It uses one terminal as a terminal point, and respectively uses the other two terminals as the other end points. The distance from the fault point to the first endpoint is measured using the D-type traveling wave principle, and the transmission line with the larger distance is taken as the fault occurrence line. Literature [19] proposed a traveling wave fault diagnosis algorithm for T-type transmission line based on the static wavelet transform. It defined the degree of membership using the known line length and the arrival time of the initial wave, and then used the degree of membership for fault diagnosis. This algorithm eliminates the effect of wave velocity on the fault diagnosis. Literature [20] proposed an algorithm based on linear equations for T-type line traveling wave diagnosis. It uses the known line length, the arrival time of the initial wave and the inherent relationship of the line itself to establish a linear equation group, and then uses the solution of the linear equations to determine the fault branch, so as to achieve the purpose of fault diagnosis. For the case where the fault occurs near the T node and the faulty branch is difficult to be identified, a algorithm of using the T node as the center to perform manual inspection along the 3 branches is adopted. Literature [21] proposed a fault diagnosis algorithm for T-type transmission line based on wavelet transform. It uses the relationship between the time difference of the current traveling wave reaching the three ends of the transmission line and the distance difference from the fault point to the three-terminal of the transmission line to establish three equations. When an internal fault occurs, the distance from the fault point to the T node calculated based on the fault branch equation must be greater than 0. In particular, when the fault occurs at the T node, the distance from the fault point to the T node is equal to 0. The algorithm has no failure to determine the dead zone and is not affected by the traveling wave speed. The literature [22] used the transmission line parameters and the initial traveling wave arrival time to calculate the wave velocity and the pseudo velocity. Then based on the principle that the velocity of the descending wave is the same in the same condition, the wave velocity is compared with the pseudo velocity to achieve the purpose of fault diagnosis.

The literature [23] pointed out that it is difficult to diagnose faults based on single-terminal power frequency fault information or traveling wave fault information. It is proposed to upload the single-end fault information of T-type transmission line to the master station and use the information of the master station to perform fault diagnosis.

In summary, the traveling wave algorithm diagnoses faults based on factors such as polarity, direction, time, speed, and line length of the traveling wave on the transmission line. The algorithm has high accuracy in fault diagnosis, but it has complicated technology and high investment.

3. Microcomputer Relay Protection Device for Transmission Line

The relay protection device needs to be used in the fault diagnosis for T-type transmission line. The relay protection device is developing with the development of the power system. In more than 40 years since the first relay protection device-the fuse in 1891, relay protection has completed four stages of development: electromagnetic protection device, transistor relay protection device, integrated circuit relay protection device. And microcomputer relay protection device. The literature [24] pointed out that microcomputer relay protection device mainly includes six parts: a central processing unit, a data acquisition unit, a communication unit, a human-machine interface unit, a clock unit, an analog quantity, and a switch quantity output unit, which respectively realize data processing, data collection. communication, keyboard command input, timing, command and data output. With the development of the times, people design different relay protection devices according to different conditions and ideas. A microcomputer relay protection device Fig. 4.

Fig 4. A microcomputer relay protection device

The literature [25] proposed a microprocessor-based microprocessor relay protection design scheme. It adopts EasyARM220 development kit which can connect or disconnect the corresponding module according to need and improve the development efficiency and the device was transplanted Wind River operating system that has strong interactivity and cut ability and can be modified according to the needs of users. The literature [26] designed a microcomputer relay protection device based on ARM controller. It focuses on the requirements of relay protection for low distribution networks in the urban network and rural network transformation. It fully considers factors such as performance and cost and makes use of LPC2214 microprocessors of the ARM7 series and $\mu C/OS-II$ operating systems to achieve a better real-time performance and be reliability, maintainability and portability. These fully reflect the advantages of ARM technology applied in relay protection system. The literature [27] proposed a design scheme of microcomputer relay protection device based on DSP and PC104 industrial computer. It implements different protection principles and solves the problems of inconspicuous and in-situ application mismatches in previous experimental devices. Literature [28] proposed a relay protection design scheme based on DSP for the relay protection of coal mine distribution network. This program uses TI's TMS320F2812 processor and independently designs some of the peripheral circuits, which forms a strongly expansive interactive relationship with a strong extensibility between the system and the host computer. The literature [29] has introduced a kind of double CPU structure microcomputer relay protection device, in which information processing adopts TMS320F2812 and microcontroller adopts C8051F041. The software design adopts a modularized idea, which makes the code hierarchy clear and has good maintainability and portability. Literature [30] introduced a dual-core relay protection device based on TMS320F2808 + N78E366A. The device has fast calculation speed, reliability, easy maintenance, strong anti-interference ability and small size. For various situations, it can meet the system functional requirements by appropriately changing the software function. Literature [31] proposed a design scheme of a microcomputer relay protection device based on a Ferrets real-time operating system and using Freckle’s 16-bit microcontroller as a processor. Its code is concise, compact, and embodies the advantages of real-time embedded systems. It is ideal for small real-time embedded systems.

In summary, relay protection device has undergone four stages of development: electromagnetic protection device, transistor relay protection device, integrated circuit relay protection device, and microcomputer relay protection device. Microcomputer relay protection device generally includes three parts: data acquisition, data processing and digital output. The existing relay protection devices propose different design solutions from the aspects of real-time performance, development efficiency and modularity.

4. Prospects and Assumptions for T-type Transmission Line Fault Diagnosis

From the above analysis, we can see that in order to save costs or restrictions such as power supply corridors, T-type transmission line will appear more and more in the power grid, and T-type transmission line fault diagnosis will also be in an increasingly important position. During the operation of the T-type transmission line, transmission line parameters may be affected by certain uncertainties or different from that provided by the relevant departments. The parameter error may be reduced by adaptive fault diagnosis. From the traditional T-type transmission line diagnostic algorithm, we can learn that when the fault current value is very small, the size of the braking coefficient has a great influence on the sensitivity and reliability of the diagnosis algorithm, but for the phase angle of the fault current, the influence is smaller, so we can study phase-based fault algorithm diagnosis algorithm. Wave speed often affects fault traveling wave algorithm. In order to prevent the diagnosis error caused by the change of wave speed, we can study the fault wave traveling protection algorithm that is independent of the wave speed. The relay protection device is responsible for the implementation of the algorithm. The fault diagnosis is closely related to its excellent performance. The relay protection device can be design in terms of rapidity, real-time and modularity to improve the reliability, accuracy and sensitivity of fault diagnosis.

5. Conclusion

This article gives a comprehensive overview of fault diagnosis for T-type transmission line. Based on the research of experts and scholars at home and abroad, the fault diagnosis algorithm for T-type transmission line is analyzed and summarized. It is pointed out that the fault analysis algorithm in the existing T-type transmission line fault diagnosis algorithm is susceptible to factors such as CT saturation, outflow of load current and so on. Traveling wave algorithm is difficult to identify with traveling wave heads and requires high sampling rate and large investment. Finally, this paper introduces the current research status of microprocessor relay protection devices in fault diagnosis of transmission lines. Based on these, the development trend of fault diagnosis for T-type transmission line is forecasted.

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