Research on Fault Location of Transmission Line based on Transient Current Traveling Wave

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Abstract

Accurate fault location of high voltage transmission line is the main measure to improve the safe and economic operation of power grid. Accurate fault location can reduce the burden of line inspection, speed up the recovery of power supply, reduce the economic loss caused by power failure, and has great social and economic benefits. The wavelet transform is applied to the analysis and research of transient traveling wave after transmission line fault. The relationship between the "mutation" of traveling wave signal and the lack of wavelet transform modulus maxima is revealed. The wavelet transform modulus maxima of traveling wave signal mark the most important fault feature in current traveling wave. In this paper, a new method for fault location of transmission lines using transient current traveling waves is proposed. Taking any "finite-length" non-fault line on the same bus as a reference line, by comparing the polarity of the reverse traveling wave surge and the corresponding forward traveling wave surge formed by the transient current of the fault line and the reference line, the traveling wave surge from the fault direction is identified, and the influence of the transient traveling wave surge from the reference line is eliminated.

Keywords

Transient Current Traveling Wave; Transmission Line; Fault Location.

1. Introduction

With the expansion of the power system, the number of high-voltage and long-distance transmission lines is increasing. The high-voltage transmission lines are distributed in a wide range, the terrain and the climate are complex and changeable across the region. It is easy to cause failures. In particular, transient faults such as flashover account for 90% to 95%, and the local insulation damage caused by such faults generally has no obvious traces, which brings great difficulties to the finding of the fault point [1]. If the fault location can be performed quickly and accurately, and the hidden danger of insulation can be discovered in time, the safe operation of the power grid can be guaranteed technically, which has huge social and economic benefits. At present, China is still in a situation of tight power supply and weak power grid structure [2]. How to improve the reliability of power supply has become an important issue. According to statistics, the vast majority of power system failures occur on transmission lines. High voltage transmission line is the main artery of power system, which is responsible for the transmission of electric energy [3]. However, a large number of transmission corridors in the system need to cross mountains, forests, rivers and lakes. Because there are many grounding faults, it is difficult to grasp the grounding resistance, and the existing relay protection devices and fault recorders cannot accurately measure the position of fault points due to the technical conditions, which brings great inconvenience to manual line inspection and wastes a lot of manpower and material resources. Therefore, it has become a challenging and practical new topic in power safety production to locate faults quickly and accurately after line faults [4]. The fault location device is also called the fault location device, which is an automatic device for determining the location of the fault point. The fault location device uses the fault location algorithm to quickly and accurately determine the fault point, which not only greatly reduces the burden of manual line inspection, but also detects faults that are difficult for people to find [5]. Therefore, it is difficult to estimate the social and economic benefits it brings to power production units. The performance of the fault location algorithm plays a decisive role in the fault location. Therefore, it is an important task for relay protection workers to study the fault location algorithm with superior performance. The reason why the transient current traveling wave can be used to measure the fault location of transmission circuit is that when the transmission line is abnormal, the fault place will generate transient traveling wave, which will form a reflected wave. Then the fault point can be determined by the characteristics of the reflected wave, and then it can be detected to ensure the normal operation of the transmission line, This is a great progress in fault detection technology [6].

2. Wavelet Transform Modulus Maximum Value Representation of Fault Distance Characteristics of Transient Current Traveling Wave

2.1 The role of fault location

With the continuous improvement of transmission capacity and voltage level of modern power system, the scale of power supply network is also expanding. The natural conditions such as geological conditions and meteorological conditions in the area where transmission lines cross are complex and changeable, and there are many factors that may cause faults. Once a fault occurs, it will not only cause direct damage to the electrical equipment, affect the system power supply, but also directly threaten the stability of the system. Fast and accurate fault location is conducive to eliminating faults and hidden troubles in time, shortening power outage time and improving power grid operation level, which has practical economic significance and social benefits. Therefore, it has become a challenging and practical new topic to locate faults quickly and accurately after line faults. According to the function of the fault location device, the practical fault location algorithm should meet the following two requirements: Accuracy is a basic requirement for the fault location algorithm. The standard to measure accuracy is the ranging error, which can be expressed in absolute error and relative error. In theory, the smaller the ranging error, the better. In fact, due to technical and economic constraints, the accuracy requirement can be met by specifying that the ranging error is not greater than a certain index. The main factors affecting the ranging accuracy are: the error of the device itself. Combined effect of load current and transition resistance. System impedance on both sides of the line. The line distribution capacitance. The line is asymmetric. The line parameters are not accurate. Robustness is another basic requirement of fault location algorithm. Robustness is a common term in the field of automatic control. The robustness of ranging algorithm mainly refers to the adaptability of the algorithm to various kinds of faults and the inhibition of comprehensive measurement error.

2.2 Transient current traveling wave

The current traveling wave signal is a kind of non-stationary signal with mutation property, and the mutation point marks that the traveling wave reaches the detection point. Wavelet transform is a very effective tool to analyze the mutation signal and detect the mutation point. The dyadic wavelet transform has translation invariance on the time axis. B-spline function has minimum support among all polynomial spline functions. Moreover, the cubic center B-spline function is proved to be asymptotically optimal for the noisy signals, so this paper uses the cubic center B-spline function as the wavelet function to perform dyadic wavelet transform on the current traveling wave signals. After the conversion of current traveling wave signal, different fault points will produce different reflected waves, and in this process, modulus maxima will appear, which can reflect the strength of the signal. To some extent, modulus maxima can clearly reflect the polarity of the signal, which makes it more convenient to analyze the signal and simplify its calculation accordingly. Practical research shows that the wavelet transform modulus maximum has a close relationship with the scale factor. The former decreases with the increase of the latter, which means that the two are negatively correlated, but this is only used with noise signals. It is other signals, and there is a positive correlation between the two. If you can make full use of this positive correlation, you can take corresponding measures to eliminate noise and extract the signal effectively.

3. Fault location of transmission line based on transient current traveling wave

3.1 Basic principle of single terminal fault location using transient current traveling wave

Cubic B-spline wavelets with symmetry and linear phase are selected to extract abrupt signals with a certain frequency from the faulty traveling wave head. The low-pass filter h[n] and the band-pass filter g[n] are as follows:

Table 1. Selection of filter

n	1	2	3	4	5	6
h[n]	-0.0984	0.0984	0.8071	0.8071	0.0984	-0.0984
n	1	2	3	4	5	6
g[n]	0	0	-0.8071	0.8071	0	0

After a line fault, the sudden change of the voltage at the fault point will produce a transient traveling wave that propagates toward both sides of the fault line at a speed close to the speed of light, forming the first reverse traveling wave surge. When the traveling wave surge reaches the bus bar of the measuring terminal, reflection and transmission will occur at the same time due to the discontinuity of impedance. The reflected wave forms the first forward traveling wave surge. After it reaches the fault point, it will reflect again, thus forming the second A reverse wave surges. Suppose the first forward traveling wave surging felt by the measuring end is ${u^+}_1(t)$, and the corresponding reflected wave at the fault point is $u\bar{2}(t)$, as shown in Figure 1.

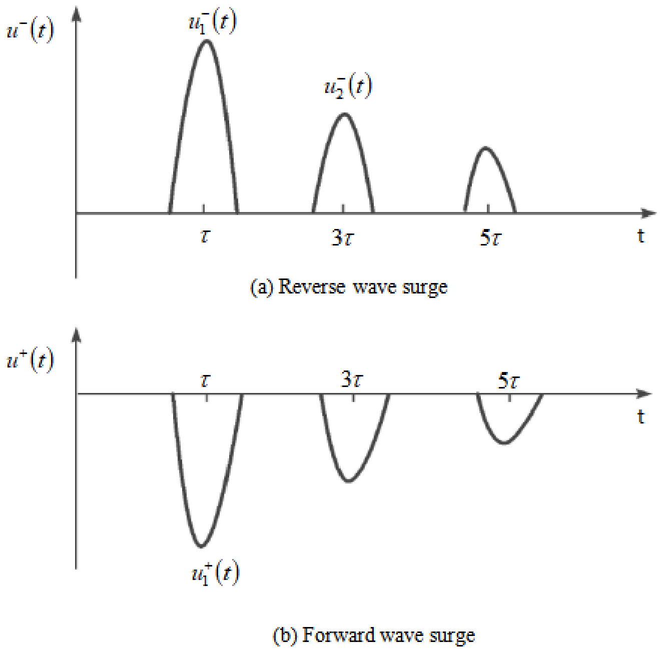

Figure 1. Directional traveling wave at the measuring end

The traveling wave relation is as follows

$$u\bar{2}(t) = KF\overset{+}{u}1(t-2^f) \tag{1}$$

Where K_F is the reflection coefficient of traveling wave at fault point. F is the propagation time of traveling wave between local bus and fault point. Therefore, as long as the time delay 2^f is measured, the fault distance can be calculated:

$$L = v^f \tag{2}$$

Where l is the fault distance. V is the wave velocity. What is felt directly at the measuring end is not the directional traveling wave, but the actual transient voltage and current, which are the result of the combination of forward traveling wave and reverse traveling wave. Directional traveling waves can be extracted by linear combination of transient voltage and transient current of measuring points with respect to wave impedance:

$$\begin{cases} u^{+} \quad (t) = \frac{u(t)+Zci(t)}{2} \\ u^{-} \quad (t) = \frac{u(t)+Zci(t)}{2} \end{cases} \tag{3}$$

Where $u^{+} \quad (t)$ is the same as the selected reference direction. $u^{-} \quad (t)$ is opposite to the selected reference direction.

Compared with the above basic facts, it can be further extended that the amplitude of the transmission component from the reflection wave of the adjacent bus to the fault line will be smaller than that of the reflection wave of the adjacent bus itself. Accordingly, the amplitude of the wavelet transform modulus maxima is smaller than that of the adjacent bus reflection. The amplitude of the transmission component reflected by the adjacent bus of a non-fault line penetrating into another non-fault line will also be smaller than that of the former. The transmission components of reflected waves from adjacent buses of a non-fault line penetrating into the fault line and other non-fault lines have the same polarity.

3.2 Application in traveling wave distance protection and fault location

In recent years, with the widespread use of microprocessor-based relay protection devices and fault recorders in the power grid, when the power system fails, both the protection and fault recorders are equipped to transmit faults to the power grid dispatching center in the form of data. The possibility of information. The proposal of relay protection and fault information management system is to improve the information and intelligent level of the dispatching system for the safe operation of the power grid, provide real-time fault information for the dispatching when the power grid fails, and effectively recover the system quickly. Although a large number of microprocessor-based protections are put into operation in the system, the configuration is still focused on the protection function itself, and less on data sharing and analysis.

When a transmission line fails, the fault traveling wave will propagate from the fault point along the fault circuit to the buses on both sides. The traveling wave fault location system mainly includes four parts: traveling wave acquisition and processing system, traveling wave comprehensive analysis system and remote maintenance system connected with PC master station, and communication channel, as shown in Figure 2.

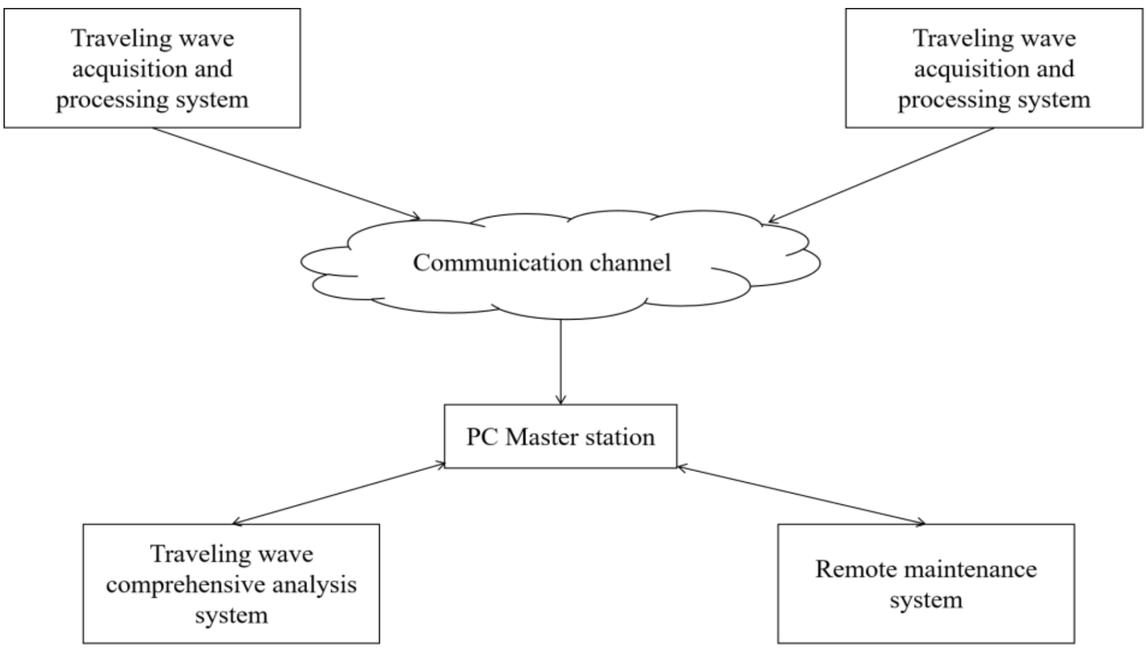

Figure 2. The overall structure of the system

The wavelet transform method is a method to realize the fault location based on the modulus maximum value of the traveling wave signal under the wavelet transform. The main feature of the wavelet transform method is that it can simultaneously observe the changing laws of the traveling wave signal in the time domain and the frequency domain to realize accurate fault location. In the above analysis, the main idea of the wavelet transform method has actually been used. The wavelet transform modulus maximum at one scale detects the initial traveling wave and the reflected wave from the fault point, but it is not yet clear on which scale the ranging is performed.

In fact, the modulus maximum value under the wavelet transform is closely related to the scale (ie frequency), and the distribution of the modulus maximum value of the wavelet transform is different under different scales. The correct identification of fault points and reflected waves can constitute traveling wave distance protection and traveling wave fault location based on the modulus maximum of current traveling wave wavelet transform.

4. Conclusions

The transient current traveling wave after a line fault contains fault information, and its fault feature is the "sudden change" of the signal. The linear combination of the transient current of the faulted line and the transient current of any "finite-length" non-faulted line on the same bus as the reference line can be used to construct the directional traveling wave of the faulted line. The imaginary reverse traveling wave caused by the terminal transient traveling wave. Under certain conditions, the imaginary reverse traveling wave has the same polarity as the second reverse traveling wave from the fault direction. This makes the conventional distance measurement method of identifying the second reverse traveling wave swell failed. Fault location technology can shorten the outage time, improve the safety and maintenance level of the system, and has practical economic significance and social benefits. In the past 50 years, electric power workers have done a lot of work in fault location of transmission lines and put forward many practical algorithms. Wavelet analysis can accurately reflect the time and location of the fault, and can be used for real-time and effective state monitoring and fault diagnosis of power system or equipment. The distance measuring device solves the problem of synchronous sampling of data at both ends of the line by using the synchronous second pulse IPPS of GPS to control the medium-speed data acquisition. By using these synchronously collected data, accurate two-end steady-state distance measurement without dead zone can be realized. In summary, it can be seen that using transient current traveling waves to locate faults on high-voltage transmission lines has great advantages. For example, this type of ranging method can determine the direction of current traveling waves, while traditional ranging methods have no direction. It is impossible to determine whether it is the traveling wave at the fault point or the traveling wave at the bus.

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