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Based on the Wavelet Function of Power Network Fault Location

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Abstract

In order to improve the measurement accuracy, in the traditional measuring method based on, by avoiding wave speed influence on fault location of transmission line method, and compares it with the combination of wavelet transform. This article selects dBN wavelet and three B spline wavelet contrast, compared them with new methods, through the Xi'an City Power Supply Bureau of the actual fault data validation. The results show that, with3 B spline wavelet and the new method combined with the location results are closer to the actual distance, its accuracy is higher than that of db3wavelet transform and a new method derived from the results, the error is far less than the db3 wavelet function, location is satisfactory.

Keywords: *fault location, single terminal method of traveling wave, mallat, dbNwavelet, 3 B-spline wavelet*

1. Introduction

With the rapid development of China's economy in recent years, China's power industry has achieved rapid development, however, along with the growing size of modern power system, failure to stop power supply as an important part of the power system, transmission lines, not only affects production , but also endanger the power system safe and reliable operation [1]. Therefore, the power system fault location is very important, has been subject to the close attention of domestic and international power production and scientific research departments.

The early 1970s, the power system has begun on the use of the traveling wave technology, but due to many constraints, such as the traveling wave signal acquisition methods, precise timing problems, has not been resolved. With the development of science and technology, the current signal converter, high-speed digital signal processing chip [2] and the development of wavelet analysis, the use of the power system provides the basic means of traveling-wave analysis method. Traveling-wave single-ended ranging, double-end D-type ranging.

Xi'an Power Supply Bureau for many years on the basis of fault location, the use of a from the wave speed limit of A-type traveling wave locating method and wavelet theory, select dbNwavelet and cubic B-spline wavelet basis functions compared to actual data validation, reducing the distance measurement error [3], and improve the ranging accuracy.

2. A Fault Location Method

A-type traveling wave generated by the point of failure ranging, according to the measuring point to the point of failure between the time and traveling wave velocity to determine the distance to fault. Positioning device developed in accordance with this principle is simple, just line one end of the installation, does not require contact with the line-side communication. Single-ended traveling wave fault location principle [4]

Traditional ranging methods such as shows, the definition of the X point of failure to measure the distance of the end of S side, the wave velocity V, T_1 fault the initial traveling wave to reach the S end of time, T_2 is the point of failure reflected wave to reach the S The end of time, $\Delta t = T_2 - T_1$ for the delay.

$$X = \frac{1}{2} V \times \Delta t = \frac{1}{2} V (T_2 - T_1) \qquad (1)$$

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Wave velocity of the traveling wave $V = 1/\sqrt{L_0 C_0}$ (L_0, C_0, respectively, the transmission line conductors per unit length inductance, capacitance, the formula of calculation is based on the lossless line) [1] for the different lines, and its parameters are not identical to the same line, even at different times, subject to electromagnetic interference, its parameters will be different, this situation led to inconsistent values of the wave velocity in different lines or different times. [5] The uncertainty of the wave velocity is bound to affect the accuracy of fault location.

The traditional method of using electronic counter, open a counter in the fault initial traveling wave arrives, stop the counter when the fault traveling wave by the point of failure reflected the end of the back line. It can be the end line to the point of failure between the time corresponding to twice the measuring point to the fault distance. The main disadvantage of this principle can not distinguish between the reflected wave of the other wave impedance discontinuity point in the reflected wave from the point of failure and system reliability is poor.

Based on the A-type single-ended traveling wave fault location method avoiding wave speed influence [6] such as Equation (6) shows, the definition of X is the point of failure to measure the distance of the end of S side, the absolute time T_0 for failure, T_1 fault initial line wave to reach the S side of the moment, T_2 at the point of failure reflection waves reach the S side of the T_3 is reflection-side bus wave to reach S end of time, L, for the Total length of transmission line, v The for Travelling Wave Speed . Displacement is equal to the velocity multiplied by time derivation is as follows

$$v(T_1 - T_0) = X \quad (2)$$

$$v(T_2 - T_0) = 3X \quad (3)$$

$$v(T_3 - T_0) = 2L - X \quad (4)$$

In (2) (3) (4) v、T0、X is the unknown parameters, the equations have:

$$T_0 = \frac{(3T_1 - T_2)}{2} \quad (5)$$

$$X = \frac{(T_2 - T_1)}{T_3 - 2T_1 + T_2} L \quad (6)$$

It can be seen from Equation (6), excluding wave velocity V in the formula for calculating the fault distance. Thus, in theory, eliminate the wave velocity ranging accuracy. Access time T by the wavelet transform. Select the wavelet basis function to transform the traveling wave line mode traveling wave line mode position difficult to accurately determine the feature points, and change another feature point position can be accurately determined for the wavelet transform domain, this feature points to determine the traveling wave time of arrival, by the traveling wave first line mode to reach the line at both ends of the time difference may determine the fault location. [7] The advantages of wavelet window function of the "microscope" function, the arrival time of the reflected wave, increasing the resolution of the time parameters, and can determine the precise moment.

3. Wavelet Transform

Traditional signal analysis tools Fourier transform is only applicable to stationary signal analysis and processing, lack of flexibility and effectiveness of the mutant signal analysis and processing. The wavelet transform has good frequency localized, a prominent component of the flexible [8] window changes highlight the fault signal time-frequency through to extract the fault information.

If the function $\psi(t) \in L^2(R)$ Its Fourier transform $\hat{\psi}(w)$ Satisfy the admissible condition (Admissible Condition).

$$C_\psi = \int_{-\infty}^{+\infty} |w|^{-1} |\hat{\psi}(w)|^2 \, dw < \infty \tag{7}$$

That is, C_ψ Bounded, then ψ A base wavelet. Base wavelet through dilation and translation, it can be a wavelet series.

$$\psi_{a,b}(t) = |a|^{-\frac{1}{2}} \psi\left(\frac{x-b}{a}\right) \tag{8}$$

In (8) a, b ∈ R, a ≠ 0 is called a dilation factor, b is the translation factor. Definition (9) on the base wavelet ψ The continuous wavelet transform.

$$\left(W_\psi f\right)(a,b) = \left\langle f, \psi_{a,b} \right\rangle = |a|^{-\frac{1}{2}} \int_{-\infty}^{+\infty} f(t) \overline{\psi\left(\frac{t-b}{a}\right)} dt \tag{9}$$

4. Wavelet Decomposition and Reconstruction

4.1. Mallat Algorithm

Mallat, 1989, in the tower of the image decomposition and reconstruction algorithm inspired, according to the multi-resolution theory proposed a fast algorithm of wavelet decomposition and reconstruction, known as the Mallat algorithm [9]. The application of the algorithm in the wavelet transform equivalent to the position of the FFT (Fast Fourier algorithm) in the Fourier transform.

The basic idea of the Mallat algorithm is as follows:

Set up $H_j f$ For energy limited signal $f \in L^2(R)$ Resolution 2^j Under the approximation, $H_j f$ Can be further decomposed into $H_j f$ Resolution 2^{j-1} Under the approximation $H_{j-1} f$ (Low-pass filter), in resolution 2^{j-1} And 2^j Between the details $D_{j-1} f$ (Of high-pass filter), and

$$c_k^{j-1} = \sum_n c_n^j < \phi_{j,n}, \phi_{j-1,k} > = \sum_n c_n^j h_{n-2k}^* \tag{10}$$

$$d_k^{j-1} = \sum_n c_n^j < \phi_{j,n}, \psi_{j-1,k} > = \sum_n c_n^j g_{n-2k}^* \tag{11}$$

Equation (10) and (11) Mallat algorithm of wavelet decomposition algorithm [6], which $\{h_k\}_{k \in Z}$ is the sequence of the corresponding filter coefficients by the scaling function of the two-scale equation can be regarded as low-pass filter; $\{g_k\}_{k \in Z}$ Can be regarded as a high-pass filter. c^{j-1} And d^{j-1} Can be seen as c^j Low-frequency signal and the detail signal, low-frequency signals [10] using wavelet decomposition algorithm can be c^j Low-frequency signals c^M The details of the signal at different frequencies. $d^M, d^{M+1}, \cdots, d^{j-1}$.

Mallat algorithm is a reconstruction algorithm is the reverse process of the decomposition algorithm, Reconstruction Equation (12) as shown:

$$\begin{aligned} c_k^j &= \sum_n c_n^{j-1} < \phi_{j-1}, \phi_{j,k} > + \sum_n d_n^{j-1} < \psi_{j-1}, \phi_{j,k} > \\ &= \sum_n c_n^{j-1} h_{k-2n} + \sum_n d_n^{j-1} g_{k-2n} \end{aligned} \tag{12}$$

4.2. Wavelet Basis Function Selected

In the process of signal analysis, wavelet basis functions [7] select is very important. Of Daubechies wavelet coefficients (dbN) has a regular, orthogonal and compactly supported, except for the N = 1, dbN wavelet with symmetry, intended for use db 3 compactly supported orthogonal wavelet [11].

B-spline function waveform is smooth and symmetrical, the wavelet function is orthonormal. Orthogonal wavelet decomposition and reconstruction of signals with good nature, and therefore, this paper intends to select the cubic B-spline wavelet db3 wavelet compared to further reduce errors, improve ranging accuracy.

4.3. Wavelet Transform Singularity Detection and Modulus Maxima

Transient signal of the power system failure, the mutation point (singular point) often contains important information such as the time of occurrence of the fault. After the failure of the traveling wave initial wave head, the point of failure reflected wave, right-side bus reflected [12] wave to reach the measurement side, the performance of the apparent singularity, which contains the fault took place, direction, voltage popular wave the polarity and amplitude information. That such information is accurate extraction will directly affect the ranging accuracy.Thus the line wave ranging signal singularity detection is particularly important.

Therefore, to detect a signal f (t) the singular point [9], only the signal wavelet transform, wavelet analysis has the frequency characteristics of the spatial localization found by the wavelet transform modulus maxima, then the point is the signal of a mutation. Signal singularity [13] detection and modulus maxima theory with a mathematical method to describe the intensity of the signal with mutations in the nature of mutations in time and change, this is the wavelet transform in the failure analysis of the information advantage.

5. Instance Validation-new Ranging Method with Different Wavelet Basis Functions Combining

Ho Village Substation, Xi'an Power Supply Bureau, from April 5, 2011, failure data. Transmission line length of 200km, the fault actual distance of 90km, the failure relative to other A phase to ground [14]. start time 0.04s, 0.02s of duration, end time of 0.06s. The acquisition of the fault current signal waveform shown in Figure 1.

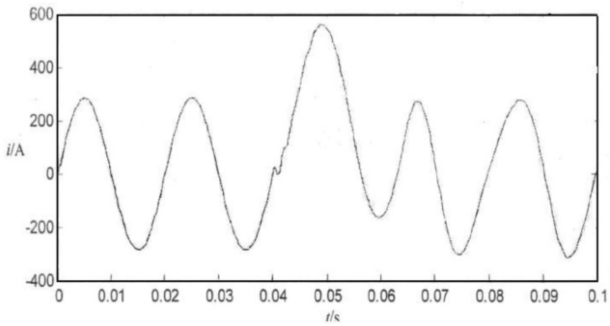

Figure 1. A Phase to Ground Fault Current Signal

The first to use the db3 wavelet wavelet decomposition, the decomposition of the wavelet coefficients of each scale shown in Figure 2.

In order to facilitate the observation of fault traveling wave to reach the moment of measurement side, the part d1 details of amplification [15]. Figure 3 shows the first layer of the wavelet coefficients of the line mode current waveform diagram t1 initial fault traveling wave to reach the S side of time. $t_1 = 40446\mu s$; t2 is the point of failure reflected waves reach the Send of the time. $t_2 = 41067\mu s$; t3 is bus reflected waves reach the S side of the moment. $t_3 = 41204\mu s$. According to Equation (6) calculated fault point F to the Ho Village to change the distance $x = (t_2 - t_1)l / (t_3 - 2t_1 + t_2)$ = 90.065km.

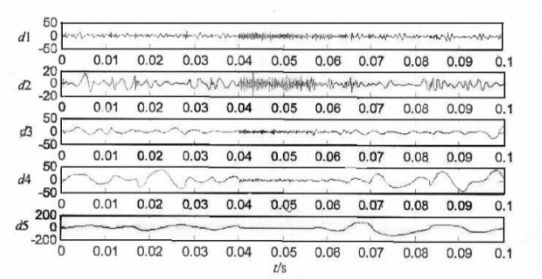

Figure 2. db3 Wavelet Decomposition 5 Layer

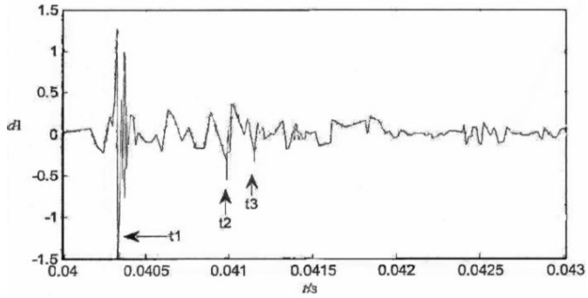

Figure 3. db3 Wavelet First Layer Wavelet Decomposition Coefficients

Followed by cubic B-spline wavelet on the A-phase ground fault line [16] mode current signal within the interval of time 0.04s ~ 0.043s five levels decomposition, the decomposition of the wavelet coefficients shown in Figure 4.

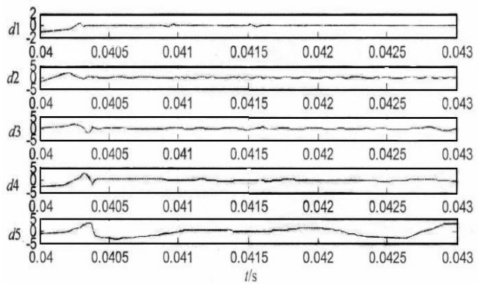

Figure 4. 3 B Spline Wavelet 5 Layer Decomposition

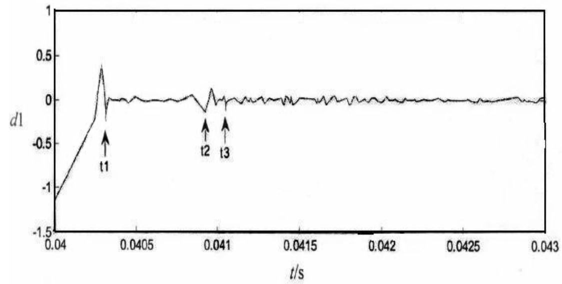

Figure 5. 3 B Spline Wavelet First Layer Wavelet Coefficients

In order to facilitate the observation of fault traveling wave to reach the moment of measurement side, [16] the part d1 details of amplification, as shown in Figure 5.

Can be seen from Figure 5 $t_1 = 40313\mu s, t_2 = 40933\mu s, t_3 = 41071\mu s$, Calculated according to Equation (6) the failure [17] point F to Ho Village to change the distance x is $x = (t_2 - t_1)l / (t_3 - 2t_1 + t_2)$ =89.985km. Ranging accuracy is equal to the error divided by the actual fault [10].

Table 1. Analysis of the Results of the Example

FFault class Type	The actual distance (km)	Wavelet Basis function	t1 μs	t2 μs	t3 μs	Measure the distance (km)	Error (km)	Accuracy%
A phase to ground so the Barrier	90	db3 wavelet	40446	41067	41204	90.065	0.065	$7.222*1$
A phase to ground so the Barrier	90	3 B spline wavelet	40313	40933	41071	89.985	0.015	$1.667*1$

In order to more clearly compare the accuracy of the wavelet basis function, the case analysis are shown in Table 1. These results indicate that the combination of 3 B-spline wavelet and a new method of ranging results closer to the actual distance, its accuracy is higher than the db3 wavelet and the results of new method, the error is far below the db3 wavelet function , Ranging effect is satisfactory [18].

6. Conclusion

In the traditional ranging method based on using a new method of avoiding wave speed influencetransmission line fault [19]. Eliminate the impact of the wave speed, the method has a high ranging accuracy and without transition resistance and fault type. Db N wavelet function and the cubic B-spline functions, respectively, and new methods of combining and wavelet theory is introduced into the transmission line fault detection and traveling wave fault location, the traveling wave header to extract the timeliness and ranging accuracy, for the protection and fault location based on traveling wave power systems provide a strong basis of theoretical analysis and examples of validation results show the effectiveness of the method has some practical value [20].

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