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Noise Reduction of Insulator Leakage Current based on EMD-CIIT

Yanhua Yin

Lanzhou University of Technology School of Electrical Engineering and Information Engineering, Lanzhou 730050, China

*401174934@qq.com

Abstract

The leakage current of an insulator is closely related to the health status of the insulator, which can comprehensively reflect the pollution degree, the degree of moisture, the voltage the insulator bears and the defects of the insulator. Therefore, a noise reduction method of insulator leakage current based on EEMD-CIIT is proposed. The noise types in insulator leakage current signal are analyzed according to the environment where the insulator is. Next, the commonly used insulator leakage current signal denoising algorithms are introduced, the advantages and disadvantages of EEMD-CIIT denoising are analyzed, and the denoising effects of various algorithms are verified by simulation.

Keywords

Insulator, Leakage Current, Reduction Processing.

1. Introduction

With the construction of hV, UHV and UHV power networks, pollution flashover of insulators on transmission lines has become one of the main hazards affecting the safe operation of power networks. Therefore, collecting and analyzing insulator leakage current signals and taking effective measures to prevent insulator pollution flasmaccidents are prerequisites to ensure the safe operation of power grid.

However, insulators have been exposed to harsh environments such as high magnetic field, high electric field, environmental pollution and humidity for a long time, and the collected signals are seriously interfered by external noises, which affects the detection effect to a large extent. How to efficiently remove the noise in the leakage current signal and retain the original useful signal plays a crucial role in accurately judging the pollution status of the insulator, and is also one of the key steps in insulator leakage current signal processing [1-2].

Liu Yong [3] established the corresponding relationship between the phase Angle difference between leakage current and operating voltage and relative humidity, ambient temperature and pollution level. It is found that the phase Angle difference decreases with the increase of relative humidity, and decreases sharply when the relative humidity reaches 100%. With the increase of ambient temperature, the phase Angle difference decreases slowly, and with the increase of pollution level, the phase Angle difference decreases. Duanmu Linnan [4] analyzed the relationship between leakage current amplitude of inferior insulator and good insulator and salt ash density and humidity.

It is found that the discharge current amplitude and pulse number increase with the deterioration of insulator. Du Xinhui [5] conducted a large number of experimental studies on tolerance characteristics and flashover characteristics, and found that the maximum leakage current and effective value increased with the increase of ESDD. The influence trend of gray density on the maximum leakage current is consistent with that of salt density on the leakage current. Yingke Mao[6][7] proposed to use the number of leakage current pulses of outdoor insulators under different

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relative humidity to predict the contamination level on the surface of insulators. The collected leakage current is divided into 80 grades according to the leakage current threshold, and one of them is analyzed by principal component analysis. The relationship among maximum leakage current, equivalent salt density and relative humidity was analyzed. It is found that the number of leakage current pulses increases with the increase of humidity and equivalent salt density. Starting from the time domain of leakage current, Gao Yongkuan [8] extracted three characteristic quantities that could represent the operation state of insulator pollution. The relationship between these three characteristic quantities and pollution degree was studied respectively. It is found that the three characteristic quantities are closely related to the pollution degree, and the maximum value is most closely related to the pollution degree. [10] analyzed the change trend of phase Angle and high-frequency component of leakage current signal under different humidity and different pollution accumulation levels.It is found that the short time discharge phenomenon increases, the third harmonic of leakage current increases, the fundamental wave amplitude increases in the long arc, and the high frequency amplitude increases. Xiong Jun [9] analyzed the long-term variation characteristics of leakage current characteristic parameters with the time of dampening, and discussed the corresponding relationship between each characteristic parameter of leakage current and pollution flashover. It was found that there was a corresponding relationship between the number of cumulative leakage current pulses and the cumulative discharge quantity with time and the occurrence of contamination flashover, that is, the number of cumulative leakage current pulses and the cumulative discharge quantity on the surface of the flashover samples increased faster than that of the samples without flashover. S. Chandrasekar.

The high frequency component can be used as the characteristic quantity to predict insulator pollution flashover. The phase Angle difference between leakage current and voltage signal can predict the state of pollution on insulator surface, but it is difficult to analyze the pollution degree on insulator surface through the phase Angle change, and select waveform distortion rate to identify the pollution degree on insulator surface.

In the research of the above paper, both the characteristic quantity in the frequency domain and the time domain can be seen, but there are few studies on the noise reduction of leakage current.

It is an important prerequisite for accurate and timely warning of insulator pollution to study how to effectively remove noise in low SNR leakage current signal and collect true and non-interfering leakage current signal.

2. Theoretical Analysis

2.1 Empirical Mode Decomposition Theory

Empirical mode decomposition (EMD) method smoothes the original signal based on the local characteristics of the signal itself, and decomposes the complex signal into a limited number of data sequences with gradually changing time characteristics and relatively independent frequency components, each of which is called an intrinsic mode function (IFM) component of the signal. The modal components obtained by EMD decomposition represent different instantaneous frequencies and still have physical significance in time domain, so EMD algorithm is very suitable for dealing with non-stationary and nonlinear signals.

2.2 Empirical Mode Decomposition Noise Reduction Theory

EMD decomposition can also be applied to signal noise reduction and filtering, which can adaptively reduce noise according to the characteristics of actual noisy signals. The most widely used noise reduction methods based on EMD include EMD time scale noise reduction method, EMD threshold noise reduction method and hybrid noise reduction method. EMD de-noising method essentially reduces noise by filtering method. The theoretical basis of filtering method is that most useful information is concentrated in low frequency band, and gradually attenuates to high frequency mode, and noise is dominant. The principle of EMD time threshold method is that after EMD decomposition, the signal-to-noise ratio of low-frequency modal component (the last component) of noisy signal is

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higher than that of high-frequency modal component (the first component). Then there is a modal component indexed by js, after which the energy distribution of useful component signals will overcome the energy distribution of noise and high frequency components of signals. Take the high-frequency modal components as noise components, eliminate them and the rest as useful signals, and reconstruct the useful signals. The most important part is the determination of js. Boudraa removes one modal component from the high-frequency modal component to the low-frequency modal component in turn, rebuilds the signal of the remaining modal components, and calculates the mean square error between the residual modal components and the last partially reconstructed signal, which is called continuous mean square error (CMSE). When the first significant change of CMSE occurs, the index of this modal component is taken as sj. This method is effective under the condition of high signal-to-noise ratio, but when the signal-to-noise ratio is low, sj misjudgment may occur.

EMD noise reduction method based on time scale is simple in calculation and has good performance under high signal-to-noise ratio. However, direct removal of high-frequency components may lead to the loss of useful features of signals and may also affect the noise reduction effect. EMD threshold denoising method is similar to wavelet denoising method, and the basic steps are as follows:

(1) EMD decomposition is carried out on noisy input signals to obtain IFMs;

(2) determining appropriate independent thresholds for each order of IFM, and performing threshold noise reduction processing on each order of IFM respectively;

(3) Reconstruct the IFMs after threshold noise reduction to obtain noise reduction signals.

3. Common EMD Threshold Denoising Algorithm based on

3.1 EMD-DT

EMD-DT directly follows the idea of wavelet threshold de-noising, thresholding each IFM component, eliminating the low-energy noise contained in each IFM, and then reconstructing the IFMs signal. EMD-DT is the first attempt to apply EMD to signal noise reduction and filtering. In fact, it is not appropriate to use threshold noise reduction method directly on intrinsic modal components, because IFMs obtained by EMD decomposition is similar to zero-mean modulated sinusoidal signal, which intermittently crosses zero points in time domain. Using threshold noise reduction directly will eliminate useful signals in the range where the signal is zero, resulting in signal discontinuity. On this basis, researchers put forward EMD-IT noise reduction method.

3.2 EMD-IT

EMD-IT combines the characteristics of intermittent zero crossing of IFMs obtained by EMD decomposition, changes the object of investigation to partial signals between adjacent zero points in IFM components, and performs threshold processing on extreme values of partial signals. Compared with the threshold function of wavelet threshold for noise reduction, its soft and hard threshold functions have changed correspondingly.

Compared with EMD-DT method, EMD-IT combined with EMD's own characteristics, adopted the idea of wavelet threshold noise reduction, realized adaptive threshold noise reduction, and retained most features of the signal.

3.3 EMD-IIT

Inspired by the shift-invariant wavelet transform, EMD-IIT is proposed. It takes advantage of the feature that the first IFM is dominated by noise after EMD processing, and by randomly changing the position of the first IFM sample, the newly generated signal is added to the sum of the remaining IFMs, so as to obtain the true noiseless signal with different noise versions. When the SNR of the first IFM is lower, the total noise variance of the newly generated noise signal is closer to that of the original signal. The EMD-IIT algorithm has excellent performance when the signal-to-noise ratio is low, but when the signal-to-noise ratio is high, the first-order IFM may contain useful signals, so randomly changing the position of sampling points may lead to the change of useful signals, thus affecting the noise reduction effect. At this time, the noise reduction effect of EMD-IT is not even as good as the simple EMD-DT method.

3.4 EMD-CIIT

Combining EMD-DT method with point structure and EMD-IT method with regional structure, an EMD-CIIT method is proposed. The main theoretical basis is that when comparing thresholds, we should not only compare the relative sizes of the interval extreme value and the threshold value, but also compare the relative sizes of the interval median value and the threshold value. When the extreme value of the interval is less than the set threshold Ti, the data contained in the whole interval is removed; When the interval extreme value is greater than the set threshold value Ti, there are two situations: when the interval median value is less than the set threshold value Ti, the EMD-DT algorithm is used to reduce noise; When the median value of the interval is greater than the set threshold Ti, EMD-IT algorithm is used to reduce noise.

4. Common EMD Threshold Denoising Algorithm based on

In this paper, insulator strings are vertically suspended in an artificial fog chamber of 2m×2m×4m. The wiring schematic diagram is shown in Figure 2.4. The voltage regulator in the figure is a moving coil voltage regulator with rated input voltage of 10kV, output voltage of 0~10.5kV and rated capacity of 2250kVA. The power supply of the sample is provided by a 2000kVA/500kV power frequency test transformer, and the protection resistance R = 16.7 kω. The voltage divider is a capacitive voltage divider with a transformation ratio of 1:1920. The test power supply is introduced into the artificial fog chamber through the epoxy pipe. The voltage and leakage current signals will be connected to the leakage current measurement system at the same time through coaxial cable. The power frequency test transformer is shown in Figure 1.

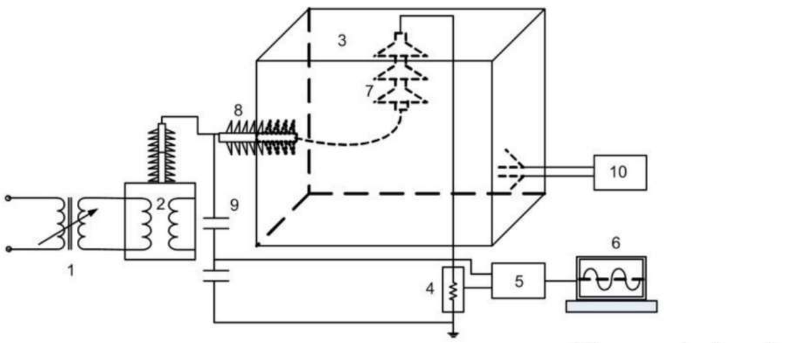


Figure 1. Schematic diagram

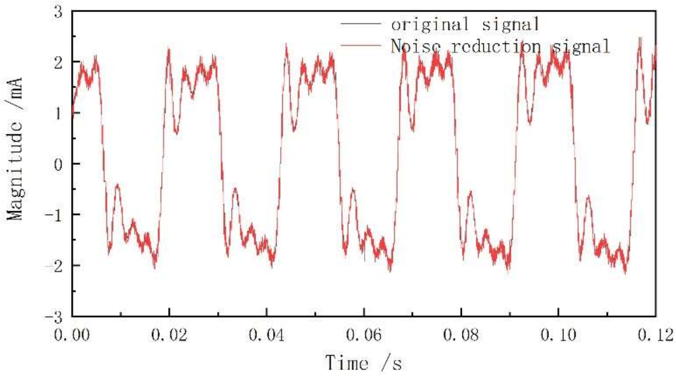
Before the test, it is necessary to remove the dirt and grease on the surface of the insulator, clean it with detergent, and then rinse it thoroughly with tap water. If a large area of water film is formed on the surface, it indicates that it is clean enough. After cleaning, hands should not touch the insulating parts of insulators. Before each smearing, the insulators should be thoroughly cleaned with tap water to remove all traces of contaminants. After cleaning, the insulators should be placed in a dust-proof container for drying.

In the test, insulator contamination refers to the quantitative brushing method recommended by IEC60507-1987 and GB/T4585-2004. According to the required salt ash density and insulator surface area during the test, the required contamination content of each string of samples is calculated, and the contamination content is weighed by high-precision electronic balance. Dissolve the filth with proper deionized water, and evenly coat all the filth on the surface of the sample. In the process of coating, try to coat evenly, and try to avoid the filth spilling. Hang it on the sample rack and let it dry naturally in the shade for 24 hours. NaCl and diatomite were selected as the salt and ash in the experiment respectively.

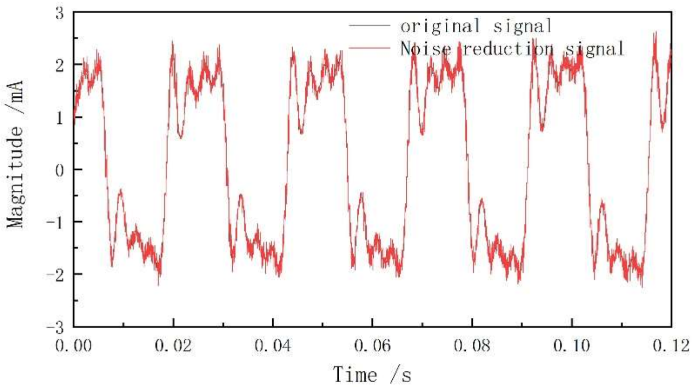
After the insulators are polluted and naturally dried in the shade for 24 hours, they are hung in a string in the center of the artificial fog chamber, so that the fog chamber is in a closed state, and the cold fog generated by the ultrasonic humidifier is used to humidify the impurities on the surface of the insulators. Two ultrasonic humidifiers are placed diagonally to supply fog, so that the fog is evenly distributed, and the humidification is stopped when water drops are generated on the surface of the insulator but do not fall.

5. Results and Analysis

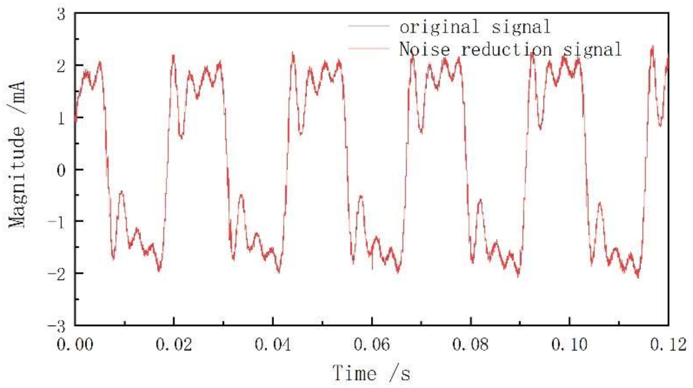
EMD-CIIT noise reduction method is used to reduce the noise of insulator leakage current signal, and the result is shown in Figure 2. Generally speaking, EMD-CIIT noise reduction method has a high degree of approximation to the real signal, and the signal after noise reduction is smooth. The EMD-CIIT noise reduction method based on hard threshold function is very close to the real signal, the local extreme points are very close to the real signal, and some points in the range around zero amplitude have certain "burrs", so the smoothness of the noise reduction signal is not good. EMD-CIIT noise reduction method based on soft threshold function processes noisy signals to get smooth lines of noise-reduced signals. However, because the soft threshold function itself is to "shrink" some modal components larger than the threshold, the noise-reduced signals as a whole have certain deviations from the real signals, especially at local extreme points, and the waveform near zero value is distorted, and the peaks existing in the real signals almost disappear in the noise-reduced signals. EMD-CIIT noise reduction method based on smooth shearing absolute deviation penalty threshold function combines the advantages of hard threshold and soft threshold function to ensure the smoothness of the noise reduction signal, but there is still the problem that the peak near zero value weakens or even disappears.



(a) Noise reduction signal after hard function processing



(b) Noise reduction signal after soft threshold function processin



(c) Smoothing absolute deviation penalty threshold function

Figure 2. Noise reduction signal

Under different threshold function conditions, the SNR, SNR gain and correlation indexes of noise reduction signals obtained by EMD-CIIT noise reduction method are compared. Table 1 shows the correlation index and signal-to-noise ratio index of noise reduction signals under different threshold functions.

Table 1. Noise reduction performance of different threshold functions

indx	hard threshold function	Soft threshold function	Smoothing absolute deviation penalty threshold function
correlation	0.9574	0.9246	0.9672
SNR	10.36	13.96	11.35

6. Conclusion

EMD-CIIT noise reduction method is an adaptive method, which can determine the number of decomposition layers according to the characteristics of the processed signal itself. This paper mainly studies the influence of the selected threshold function on the noise reduction performance of EMD-CIIT method. In noise reduction, the hard threshold function can make the noise-reduced signal approximate to the real signal to the greatest extent, but there may be non-derivable "burrs" around the amplitude of 0. The soft threshold signal can ensure that the noise-reduced signal can be derivable everywhere and the curve is smooth, but it will cause system deviation. The threshold function of punishing the absolute deviation of smooth shearing can combine the advantages of both, and approach the real signal as much as possible on the basis of ensuring the smoothness of the noise-reduced signal. The modification mode of the first modal air volume can also affect the smoothness of the signal to a certain extent, but in terms of noise reduction performance, there is little difference between circ and perm. After the EMD-CIIT noise reduction of the simulated fault vibration signal of the fan, the axial frequency component of the spectrum is clearer than that before the noise reduction, the high frequency noise is almost completely eliminated, and the quasi-separability of the signal is obviously improved.

Acknowledgments

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