A Novel Method to Restrain Ambient Noise Interference in Transformer Noise Test

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Abstract. A preprocessing method based on wavelet packet decomposition and spectral subtraction algorithm is proposed in this paper. The tested original noise signal is decomposed with the wavelet packet analysis. It is divided into several bands with different frequency range. In these bands, the noisy signals are further processed by spectral subtraction method. The theoretical analysis result shows that the proposed method is effective in restraining the influence of surrounding noises on the result of transformer noise measurement. The proposed method can be referenced for the noise measurement of power transmission and transformation projects.

1. Introduction
Accurate detection of transformer noise is of great significance for environmental impact assessment, acceptance and operation [1-4]. However, for outdoor transformers, the surrounding acoustic environment is relatively complex. When noise detection is carried out, the measurement process is often vulnerable to the interference of external environmental noise, such as birds, insects, etc, which has a serious impact on the transformer noise test results.

This paper presents a preprocessing method of transformer noise measurement based on the combination of wavelet packet decomposition and spectral subtraction. Because there are some differences between the time-frequency characteristics of the external environment noise and the transformer noise, firstly, wavelet packet analysis algorithm is used to decompose the transformer noise signal in time-frequency, and then the decomposed wavelet signal in each frequency band is processed by spectral subtraction speech processing, so as to effectively eliminate the influence of the noise around the substation in the measurement signal. The proposed method has reference significance for the accurate detection of transformer or substation noise.

2. Preprocessing method

2.1. Wavelet packet decomposition
A wavelet packet function can be defined as [5]

\[ W_{l,k}^n(x) = 2^{l/2} W^n(2^{-l}x - k) \] (1)

Where \( n \) is the modulation parameter, \( l \) is the scale level, \( k \) is the localization parameter.
The wavelet packet functions can be defined with the following sequence of recursive functions.

\[ W^{2n}(x) = \sqrt{2} \sum_k h(k)W^n(2x - k) \]  

\[ W^{2n+1}(x) = \sqrt{2} \sum_k g(k)W^n(2x - k) \]  

Where \( h(k) \) and \( g(k) \) are respectively the low-pass and high-pass finite impulse filters.

### 2.2. Spectrum subtraction speech enhancement technology

Spectral subtraction is an effective method to deal with broadband noise. On the assumption that the noise \( r(n) \) and the speech signal \( s(n) \) are independent of each other, the noise power spectrum \( P_n(\omega) \) is subtracted from the power spectrum \( P_y(\omega) \) of the noisy speech signal \( y(n) \) so as to obtain a relatively pure speech spectrum, as shown in Fig. 1. In the figure, \( \Psi(\omega) \) is the phase spectrum of the mixed noise signal.

![Figure 1. Principal diagram of the speech enhancement technique](image)

The noisy signal is divided into frames, and the windowed Fourier transform of the \( \lambda \) frame signal is as follows [6]:

\[ Y(k, \lambda) = S(k, \lambda) + R(k, \lambda) \]  

Let \( P_y(k, \lambda), P_s(k, \lambda) \) and \( P_r(k, \lambda) \) represent the power spectrum of the \( \lambda \) frame of signals \( y(n), s(n) \) and \( r(n) \), respectively.

\[ P_s(k, \lambda) = P_y(k, \lambda) + P_r(k, \lambda) \]  

Since the noise of transformer body is almost the same before and during the occurrence of external environmental noise, the power spectrum of transformer body noise can be estimated by the "silent section" when the environmental noise does not occur.

\[ P_s(k, \lambda) = \begin{cases} P_y(k, \lambda) - P_r(k, \lambda), & P_y(k, \lambda) < P_r(k, \lambda) \\ 0, & P_y(k, \lambda) > P_r(k, \lambda) \end{cases} \]  

### 3. Transformer noise signal process

As shown in Fig. 2, the sound pressure level of noise signal \( s_1 \) of an actual 110kV main transformer is 59.8 dB(A), and that of "birdsong" signal \( s_2 \) is 60.4 dB(A). The mixed sound signals of different sources in the air are the result of linear superposition of sound pressure signals of each sound source. Assuming that the superposition factor is 1.2 and the signal-to-noise ratio is 27.7 dB, the mixed signal \( s_m \) is
The sound pressure level is 63.1 dB (A), and the signal-to-noise ratio is 27.7 dB. Obviously, there is a big difference between the measured noise level and the actual noise level, and the error is 3.3 dB (A).

The db4 wavelet basis function and Shannon entropy standard are used to decompose the mixed signal $s_m$ in three layers. The decomposition results are shown in Fig. 3. It can be seen from the figure that birdsong is mainly concentrated in the frequency band above 1 kHz.

Since there is no bird noise in the first 1s of the original acoustic signal, four frames of data in this period can be selected as the "silent section" to solve the power spectrum. The frame length is 882 and the frame shift is 441. Spectral subtraction is used to filter the signal $s_{131} \sim s_{137}$. After FFT inverse transformation, the pure transformer noise signal $P_t$ and bird noise signal $P_b$ are separated as shown in Fig. 4. It can be seen that the transformer noise source signal $s_1$ and the separated pure transformer noise signal $P_t$, bird noise source signal $s_2$ and the separated pure bird noise signal $P_b$ waveform are very consistent.

![Figure 2. Transformer and background bird noise](image)

![Figure 3. Wavelet packet decomposition of the original transformer noise](image)
The spectrum comparison of transformer noise source signal $s_1$ and the separated pure transformer noise signal $P_t$ is shown in Fig. 5. The spectrum distribution and amplitude have a high consistency, and the spectrum correlation coefficient is about 1.0. After sound pressure level calculation, the $P_t$ and $P_b$ sound pressure levels of the separated pure transformer noise signal $P_t$ and bird song signal $P_b$ are 59.5db (A) and 60.6db (A), respectively, which are 0.3dB (A) and 0.2db (A) from the source signal respectively. Before and after pretreatment, the correlation coefficient of transformer noise signal is 0.9979, and that of interference noise signal is 0.9667. It can be seen that the measurement accuracy of transformer noise signal is greatly improved after filtering Pretreatment Based on wavelet packet decomposition and spectral subtraction, and the influence of "bird singing" background noise on transformer noise test results is effectively reduced.

4. Conclusion
This paper presents a preprocessing method of transformer noise measurement based on wavelet decomposition and spectral subtraction. Due to the difference between the external environment noise and the transformer noise in time and frequency domain, a filtering method combining wavelet packet decomposition algorithm with spectral subtraction speech enhancement technology can be used to
decompose the transformer sound signal in time-frequency domain by using wavelet packet analysis, and then the decomposed wavelet signal of each frequency band is processed by spectral subtraction speech processing, so as to effectively eliminate the environmental noise around the substation in the measurement process.

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