Research on Harmonic Detection Method Based on Compound Algorithm

Chun-Yan Wang

ABSTRACT

The accurate detection of harmonics is an important part of studying the harmonic problem of power system. In this paper, considering the characteristics of wavelet transform and Fourier transform, combining the two methods, using db8 wavelet transform to eliminate the transient components and noise, and then use the Blackman-Harris window Fourier transform to extract every harmonic, implements the power grid harmonic amplitude extraction and more accurately. The simulation model and analysis spectrum characteristics are carried out by MATLAB, and the RMS value of each harmonic current is also carried out by MATLAB. This method can improve the accuracy of harmonic detection.

Key words: harmonic detecting, wavelet analysis, the windowed FFT, two phase

Introduction

With the rapid development of power electronic technology, nonlinear load increasing, lead to power system harmonic distortion is more and more serious, precise analysis and detection of the harmonic in power system become more and more important. Different types of harmonics in the grid produce different types of harmonics. At present, for the harmonic detection is mainly based on fast Fourier transform and its improved algorithm, as well as time series analysis and neural network method [1], because of the Fourier transform analysis of harmonic is simple and effective, and can accurately every harmonic analysis of stationary signal, so it has been the main methods of power system harmonic analysis. However, with the increase of the harmonic content of the power grid, the components become more and more complex, the transient mutation and other unsteady components become more and more prominent, and it becomes very difficult to analyze the harmonics by FFT only.

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Time-frequency characteristics of wavelet transform are flexible, can accurately determine the signal mutation moment, filter out interference signal, to extract information from signal effectively, through scaling and translation operation functions such as the function or signal multi-scale refinement analysis, thus become an important theoretical tool in the research of harmonic detection in recent years. However, wavelet analysis has a large calculation of harmonic amplitude, and there is a certain spectrum "crosstalk" problem. Using wavelet transform, there are some defects such as unconcentration of window energy and spectrum aliasing. Combining wavelet transform and Fourier transform, the effect of the unsteady component on the extraction of the amplitude of the harmonic amplitude is obtained by using the Fourier transform.

**The principle of two-stage harmonic detection of power grid**

**Analytical method**

The whole algorithm is divided into two stages, which is called two-stage method. The transient perturbation is analyzed by combining wavelet transform and Blackman - Harris windowing Fourier transform.

In the first phase, the discrete wavelet transform is used to analyze the components of unsteady harmonic, noise and discontinuous point, and then remove unsteady harmonic, noise and intermittent points from the original signal. The second phase is the Fourier transform of the Fourier transform to extract the harmonic amplitude of the steady-state component. The schematic diagram of this scheme is shown in the figure 1.

![Figure 1. Two-stage method diagram.](image)

**Discrete wavelet transform**

Set \( f(t) \in L^2(R) \), \( \psi(t) \) for female wavelet, Its Fourier transform is \( \hat{\psi}(\omega) \). If \( \psi(t) \) satisfies the permissible condition

\[
C_{\psi} = \int_0^\infty \left| \hat{\psi}(\omega) \right|^2 d\omega < \infty
\]

(1)

The continuous wavelet transform of \( f(t) \) is:

\[
\mathcal{W}(ab) = \left| f, \psi_{ab} \right| = \left| a \right|^2 \int f(t) \overline{\psi(t/b)} dt
\]

(2)
In general, continuous wavelets are discretized. Set \( a = a^j, b = k a^j b^j, j \in \mathbb{Z} \), The extension step \( a^j \neq 1 \) is the fixed value. Suppose \( a^j > 1 \). The discrete wavelet function is:

\[
\psi_{j,k}(t) = a^j \psi\left(\frac{t-kb}{a^j}\right) = a^j \psi\left(a^{-j} t - kb\right) \tag{3}
\]

The discrete wavelet transform coefficients are expressed as follows:

\[
C_{j,k} = \int_{-\infty}^{\infty} f(t) \psi_{j,k}^*(t) \, dt \leq f \tag{4}
\]

The reconstruction formula is:

\[
f(t) = C \sum_{-\infty}^{\infty} \sum_{-\infty}^{\infty} C_{j,k} \psi_{j,k}(t) \tag{5}
\]

\( C \) is a constant that has nothing to do with the signal.

**Daubechies (dbN) wavelet**

Daubechies wavelet is a small wave in engineering. In addition to dBL wavelets, other wavelets have no definite expression, but the square modulus of the transformation function \( h \) is determined. dbN wavelet is a compact support standard orthogonal wavelet, which makes the discrete wavelet analysis possible.

The effective support length of small wave function \( \psi(t) \) and scale function \( \phi(t) \) is \( 2^{N-1} \), and the number of vanishing moments of the wavelet function \( \psi(t) \) is \( N \). dbN has orthogonality, but most have no symmetry, and its orthogonality increases with the increase of \( N \). The larger the \( N \), the more orthogonality, the better the local. But the delay in signal processing is also longer. \( N \) larger wavelet series, such as db10 db20 etc., when the line into the power system harmonic analysis, although has better effect of frequency band division, but also significantly increased the calculation time, could not reach the requirements of real-time detection. However, the small series of small waves (such as db3) in the order of the first order, because of the small number of the moment of the vanishing moment, the frequency band of the division is relatively rough, which will lead to greater errors in the harmonic analysis of the power system. In order to reduce the leakage and aliasing of the spectrum, the wavelet function is required to have the good frequency domain characteristics, considering the computational efficiency of the algorithm, so select the db8 wavelet [3].

**Simulated analysis**

**Spectral features**

The harmonic components of the power grid contain unsteady harmonic components, such as random noise, mutation waveforms and harmonic components attenuated by exponential law. In this paper, a representative harmonic signal model is selected, which contains 3, 5, 7 subharmonic components, noise signals and 11 harmonic components attenuated by exponential form. The function model is shown in figure 2.
In the first phase, db8 wavelet function is selected for wavelet analysis. The second phase of the separation of the signal uses the Fourier transform of the Fourier transform to calculate the harmonic amplitude.

The window function used is the Blackman_harris window, and the window expression is:

\[ a[k + 1] = 0.35875 \cos(2\pi k/n) + 0.48829 \cos(4\pi k/n - 1) - 0.14128 \cos(6\pi k/n - 1) \]  

This window function can effectively reduce the leakage of the spectrum.

The amplitude-frequency characteristics obtained by the simulation model of the FFT algorithm are shown in FIG. 3. The amplitude-frequency characteristics obtained by two-stage simulation are shown in FIG. 4. In figure 3, as a result of FFT algorithm in cannot eliminate signal attenuation harmonic component, the form of the index at the same time under the influence of noise signal, amplitude characteristic curve of jitter is larger, and the noise signal of each frequency amplitude accuracy have great influence. In figure 4, the amplitude-frequency characteristic curve is smooth and the frequency amplitude accuracy is higher, it can be seen that the first phase of the unsteady component and the noise signal, basically eliminated their effects on signal amplitude frequency characteristics.
Comparison of harmonic amplitude

Through MATLAB software, the model USES db8 wavelet function to decompose 4 layers. The sampling frequency is 3.2KHz and the sampling points are 1024. The decomposition node (4, 0), (4, 1), (4, 2) and (4, 3) contain the information of the base wave, one harmonic, three harmonics and five harmonics of the model signals. Using the current representation of wavelet packet coefficient, the RMS value of each harmonic current in the signal is calculated, and the harmonic amplitude is compared with that of using the FFT algorithm and two-phase method, as shown in table 1.

Table 1. The amplitude of the harmonic simulation.

<table>
<thead>
<tr>
<th>Harmonic Current Amplitude</th>
<th>Theoretical value</th>
<th>FFT</th>
<th>Wavelet packet</th>
<th>Two-phase method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental current amplitude</td>
<td>1.000</td>
<td>0.997</td>
<td>0.998</td>
<td>0.998</td>
</tr>
<tr>
<td>Three-time harmonic amplitude</td>
<td>0.333</td>
<td>0.319</td>
<td>0.325</td>
<td>0.331</td>
</tr>
<tr>
<td>Five-time harmonic amplitude</td>
<td>0.200</td>
<td>0.193</td>
<td>0.192</td>
<td>0.198</td>
</tr>
<tr>
<td>Seventh-time harmonic amplitude</td>
<td>0.143</td>
<td>0.121</td>
<td>0.136</td>
<td>0.141</td>
</tr>
</tbody>
</table>

Using wavelet transform stripping noise signal and the transient signal, then FFT algorithm can be used to calculate harmonic amplitude, not only to eliminate the noise signal and the influence of unsteady component of FFT algorithm, at the same time, greatly reduces the spectrum aliasing effect on harmonic amplitude extraction. As can be seen from table 1, the two-phase method is more accurate than the other two methods.

Summary

This paper combines the advantages of wavelet transform and Fourier transform, is put forward for harmonic analysis using short time disturbance, use db8 wavelet transform and Blackman - Harris, windowing Fourier transform method of comprehensive analysis, the principle of wavelet denoising contains noise and harmonic power signal processing, using the fast Fourier transform principle, analyze the processed signal. This method is suitable for use in harmonic detection devices.

References