Research on Harmonic Analysis and Detection Based on Improved Wavelet Packet Inverter

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Abstract: This paper introduces the basic concepts of harmonics in power system, and expounds the basic principles of harmonic detection algorithms such as Fourier transform, short wavelet transform and wavelet packet transform. The effectiveness of the proposed algorithm is verified by simulation, which shows that the improved wavelet packet algorithm can achieve the uniform division of the harmonic signal frequency band, and improve the detection accuracy of the harmonic signal. Wavelet packet transform could detect the fundamental and harmonic components of the original signal, which is most suitable for the detection of harmonic signals.

1. Introduction
With the development of power electronics technology, control theory, microelectronics technology and digital control, the advantages of AC drive system, such as simple structure, high reliability and good stability, are comparable to those of DC drive system. The gradual replacement of DC drive system by AC drive system has become an inevitable trend and main characteristic of modern electric drive. AC motor can be divided into synchronous motor and asynchronous motor according to the different speed. No matter what type of AC motor, there are strict requirements on small, lightweight, high output power, high speed and so on. With the gradual improvement of the functions of electrical products, more and more electrical products are equipped with motors and inverters. Inverter is the core part of AC motor speed control system. Its output current and voltage harmonic content directly affect the quality of motor rotation. In the AC motor system, although the proportion of harmonic current and voltage in the fundamental current and voltage is not large, it will lead to additional loss, total efficiency reduction, fluctuating torque, noise and other hazards. Therefore, it is of great significance to analyze and detect the harmonics of the inverters.

2. Common methods for harmonic analysis of inverters

2.1 Inverter output harmonics analysis
At present, the traditional SVPWM technology is often used in two-level inverters, which achieves good output results, but there are still harmonics that are not conducive to operation and do not achieve the ideal effect of harmonic suppression. Therefore, it is particularly important to analyze the harmonics generated by the inverters and find ways to suppress the harmonics of the inverters. Under ideal conditions, the output voltage harmonics of three-phase symmetrical inverters do not exist, and the integer and even harmonics of three-phase symmetrical inverters do not exist. The output voltage of the inverter contains fundamental wave and harmonics, which will produce corresponding electromagnetic torque in the motor and affect the operation quality of the motor. In view of the harm caused by harmonics, a voltage filter can be designed by using the harmonic characteristics of the
output voltage of the inverters, which can suppress the output harmonics of the inverters at the same time, and the average DC bus current mechanism can also be introduced to suppress the output harmonics of the inverters. At this time, if we know the harmonic situation of the inverters, it has great significance to suppress the harmonic. Figure 1 below shows the main circuit structure of a two-level three-phase inverter.

![Inverter schematic](image)

**Figure 1. Inverter schematic**

### 2.2 Fourier Transform harmonic analysis

Fourier transform is the most commonly used method for harmonic analysis, which means that an arbitrary signal function can be expressed in the form of the sum of infinite sinusoidal signals of different frequencies, as shown in formula 1 below.

\[
F(\omega) = \int_{-\infty}^{+\infty} f(t)e^{-j\omega t} dt
\]

In formula 1, \(F(\omega)\) is the spectral function of function \(f(t)\), and its inverse transformation is:

\[
f(t) = \frac{1}{2\pi} \int_{-\infty}^{+\infty} F(\omega)e^{j\omega t} d\omega
\]

Generally speaking, the function \(f(t)\) is the original function, while the function \(F(\omega)\) is the image function of the Fourier transform. The original function and the image function form a Fourier transform pair. In the field of communication or signal processing, Discrete Fourier Transform is widely used because most of the applications of signals are discrete. Fourier transform is a very effective tool, which can analyze and process many signals. In scientific research and engineering application, it is a powerful analytical method, which establishes the transmission of information between time domain and frequency domain.

### 2.3 Wavelet Transform harmonic analysis

Traditional signal theory is based on Fourier analysis, but Fourier transform has some limitations because of the contradiction between localization in time domain and frequency domain. Wavelet transform is an improvement of Fourier transform in practical application. It is a new transform analysis method. It inherits and develops the idea of localization of short-time Fourier transform, and overcomes the shortcomings of window size not changing with frequency. It can provide a time-frequency window that change with frequency. It is an ideal tool for time-frequency analysis and processing of signals. In recent years, with the development and application of wavelet theory, the mathematical theory and method of wavelet transform have attracted more and more attention. Wavelet transform analysis of power system harmonics satisfies both time domain and frequency domain characteristics, which could be effectively applied to detect and extract various types of electrical interference signals.

### 3. Improved wavelet packet harmonic analysis method

Wavelet packet provides a more refined method for signal analysis. It divides the frequency band into multiple levels, further decomposes the unsubdivided part of the pupil frequency in the
multi-resolution analysis, and adaptively selects the corresponding frequency band according to the characteristics of the analyzed signal, matching it with the signal spectrum, thus improving the time-frequency decomposition rate. In addition, it can select the corresponding frequency band adaptively according to the characteristics of the frequency band, and improve the time-frequency resolution in signal analysis. Therefore, the wavelet packet has a wider application value.

3.1 Problems of traditional wavelet packets
When the wavelet packet is decomposed, the details of each layer after the wavelet decomposition continue to be decomposed by the decomposition filter. For the wavelet packet, the proper selection of the wavelet packet basis function has a good effect on signal analysis. If the selection is not appropriate, it will lead to no solution. The selection of wavelet packet basis is a key problem to be solved in engineering application of wavelet analysis. Different wavelet packet bases are chosen to solve the same problem and the results are different. At present, there is no specific method to select the wavelet packet basis. The most widely used method is to judge the quality of the selected wavelet packet basis by comparing the errors between the results of different wavelet packet analysis and the theoretical results, so as to select the wavelet packet basis function. Therefore, it is particularly important to select a suitable wavelet packet basis for signal harmonic analysis.

3.2 Improved Wavelet Packet Harmonic analysis
The biggest advantage of wavelet packet is that it has good time-frequency resolution, and the high-frequency part of the signal can be subdivided continuously. Therefore, it has application prospects in the analysis of unsteady harmonics. However, there are two key problems for wavelet packet: one is to reduce frequency aliasing, and the other is to select a suitable wavelet packet base. Therefore, the improvement of the wavelet packet algorithm should start with reducing frequency aliasing and selecting the optimal binary tree for the best wavelet packet basis. The biggest advantage of wavelet packet is that it has good time-frequency resolution and can be subdivided in the high frequency part. Therefore, it has great application prospects in the analysis of unsteady harmonics.

4. Analysis of Improved Wavelet Packet Harmonic detection platform
To verify the advantages of improved wavelet packet in harmonic detection, two harmonic detection platforms are built, one is the harmonic detection platform built by LabVIEW itself, and the other is the harmonic detection platform based on improved wavelet packet combined with MATLAB. When both of them are input into the designed simulation signal, it can be found that the harmonic detection platform based on improved wavelet packet can more accurately detect each harmonic. In order to verify the applicability of the improved wavelet packet in harmonic detection of inverters, the current signal from the inverters in Simulink motor simulation model is imported into LabVIEW, and the harmonic of the signal is detected by the improved wavelet packet harmonic detection platform. From the waveform of current signal in LabVIEW, it can be seen that there is a sudden change with time, which is consistent with Simulink's simulation chart. It shows that the improved algorithm has high accuracy, which means that the improved algorithm has great advantages in harmonic detection of inverters.

5. Conclusions
Based on the existing problems of traditional wavelet packet analysis and the advantages of virtual instrument technology, the overall design scheme of harmonic analysis and detection based on improved wavelet packet inverters is proposed. The main idea of the improved wavelet packet algorithm is to design filter banks to reduce frequency aliasing in the process of wavelet packet decomposition and reconstruction, and to improve the wavelet packet algorithm through the optimal wavelet packet base and the optimal wavelet packet tree. Firstly, MATLAB software is used to simulate and verify the above improved wavelet packet method, and then LabVIEW is used to design and improve the harmonic detection platform of wavelet packet inverters. From the verification results, it can be seen that compared with the traditional wavelet packet, the improved wavelet packet has
higher accuracy in reconstructing high-order harmonic signals, and at the same time, the problem of frequency aliasing has been greatly improved.

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