ISSN: 2414-1895 DOI: 10.6919/ICJE.202012_6(12).0024

Harm and Detection of Harmonics in Ship's Shore Power System

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Abstract

In recent years, as international organizations such as Europe, the United States, IMO, and various local environmental protection departments have paid more and more attention to the management of pollution reduction, non-renewable energy conservation, and protection of the ecological environment, it has become inevitable to build a green and environmentally friendly port. Auxiliary engines stop running, and daily electricity for ships is supplied from shore. Therefore, major ports around the world are vigorously constructing ship shore power inverter power systems. Although the inverter in the marine shore power inverter power supply system can output better results in the process of converting the electricity system and transmitting the electric energy, the suppression of harmonics is not satisfactory, which makes the inverter exist during operation A large number of harmonics pose a major hazard to the safe operation of the ship's shore power inverter power supply system and the ship's confidential instrumentation. More accurate harmonic detection methods are of great significance whether it is effective prevention of harmonic pollution or the safe and efficient operation of marine shore power inverter power supply systems. This article will improve the Fast Fourier Transformation (FFT) method through the window function to improve the detection accuracy of the harmonics in the circuit.

Keywords

Shore Power Inverter, Window Function, Harmonic Detection.

1. Introduction

In recent years, with the deterioration of the greenhouse effect and globalization, people's awareness of energy conservation and emission reduction, and protection of the ecological environment has gradually increased. As one of the main sources of environmental pollution, nitrogen oxides emitted by ships have always attracted people's attention. In order to reduce the pollution caused by ships to the ecological environment and the noise and vibration caused by the operation of auxiliary machinery to port crews and residents in neighboring communities, after the ship arrives at the port, the ship must stop the main engine and auxiliary machinery of the ship. Electricity supply. However, because the shore power of my country's ports uses 380V/50Hz power system, and most ocean-going ships in foreign countries use 440V/60Hz power system, the shore power supply of ships in Chinese ports cannot directly supply power to ocean-going ships. Generally, IGBT inverter circuit is used as the high-power inverter power supply realized by high-power devices (400KW and above) to realize the three-phase power inverter from 380V/50Hz to 440V/60Hz to provide AC power for ocean-going ships in the port. Under ideal conditions, the three-phase inverter power supply has very low even-numbered harmonics and three integral multiples of harmonics in its output current. However, in actual working conditions, the output current of the three-phase inverter power supply will contain various harmonics, which will affect the normal operation of electrical equipment in the ship's shore power grid. At the same time, with the R&D and application of many sciences and technologies, more

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and more precision electrical equipment is equipped on ships. While providing more intelligent and accurate services for human beings, it also makes modern ships increasingly demanding power quality. Increase. Therefore, the detection of harmonics in the ship's shore power system is very necessary, and it is the basic guarantee to ensure the reliable and stable operation of the ship's shore power inverter power supply system and the ship's electrical appliances. Finding a more accurate harmonic detection and analysis method is of great significance for the safe and efficient operation of marine shore power inverter power systems.

2. Harmonics and their hazards

Strictly speaking, a harmonic is a sine wave component of a period of electricity, and its frequency is an integer multiple of the fundamental frequency [1]. When there are a large number of nonlinear loads in the operating power system, a sine wave that is an integer multiple of the fundamental frequency, that is, harmonics, will be generated in the power grid. At present, it is found that the harmonics in the marine shore power inverter power grid system are mainly high-order harmonics. Under ideal operating conditions, the three-phase voltage output by the ship's shore power inverter is balanced, its frequency and square root are constant, and the current and voltage waveforms will not be distorted. But when there are harmonics in the system, the current and voltage waveforms will be distorted. The main reason for the harmonics generated by the ship's shore power inverter is usually due to the existence of a large number of nonlinear loads in the ship's shore power grid, which causes the ship's shore power grid to generate harmonics or the output voltage of the inverter power supply itself has some harmonics wave.

The generation of harmonic current and harmonic voltage will seriously affect the stable operation of the ship's shore power inverter power supply system. The main hazards are:

(1) Distorting the output voltage and current of the ship's shore power inverter power supply, affecting the safe and stable operation of the shore power grid.

(2) When the power grid contains a lot of harmonics, it will affect the normal operation of the capacitor. Due to the existence of harmonic currents, capacitor overload and even system resonance problems are unavoidable, and more serious will cause the capacitor to be burned out, making it impossible to use it normally.

(3) When there are a large number of harmonics in the power grid, the copper loss and iron loss of the transformer will increase, causing local heating of the transformer and even vibration, which will affect the normal operation of the transformer.

(4) Harmonics will reduce the efficiency of asynchronous motors in the power system, and in severe cases, they will cause mechanical vibration and affect the service life of asynchronous motors.

(5) When there are a large number of harmonics in the power system, the measuring instrument will not work normally, resulting in a decrease in its measurement accuracy.

(6) Harmonics also cause interference to the surrounding power electronic equipment, affecting the normal operation of other equipment.

3. Harmonic detection

With the rapid development of science and technology, various electronic instruments have entered daily use, and the harmonic problem of AC power systems has become increasingly prominent. Therefore, the detection methods of power system harmonics have begun to increase, which can be roughly divided into frequency domains. There are two types of theory and time domain theory. In the initial detection of harmonics, analog filtering methods are basically used, guided by frequency domain theory. The biggest advantage of this method is that the circuit structure is relatively simple and can filter out some specific frequency harmonics, but its shortcomings are also very obvious. The error of this method is relatively large, so it is difficult to obtain ideal phase-frequency characteristics and amplitude-frequency. With the gradual progress of science and technology, analog filtering

ISSN: 2414-1895
DOI: 10.6919/ICJE.202012_6(12).0024

methods have been gradually eliminated. Accurate harmonic detection for marine shore power inverters can effectively prevent harmonic pollution [2]. Now the most widely used and more classic harmonic detection method is the Fast Fourier Transformation (FFT) method, which is widely used due to its relatively simple algorithm principle and easy implementation of hardware circuits. However, the use of FFT algorithm for harmonic detection is asynchronous sampling, and the shortcomings are also very obvious. It often has fence effect and spectrum leakage, which seriously affects the accuracy of harmonic detection [3]. However, if the window function can be used to improve it, not only can the spectrum leakage phenomenon be effectively suppressed, but also the discrete signal spectrum can be corrected. In addition, the error caused by the fence effect can also be reduced to a certain extent. Therefore, by using windowed Fourier transform to complete the harmonic detection and analysis, it is hoped to effectively improve the accuracy of harmonic detection.

4. Improved FFT plus Hanning window harmonic detection

Because the window function can well suppress the leakage of the spectrum, the windowed FFT algorithm will have a high accuracy for harmonic detection under asynchronous sampling [4]. Hanning window function can not only suppress the spectrum leakage very well, but also has superior side-lobes, so it is widely used in power harmonic detection [5]. The traditional Fourier algorithm will be improved by adding the Hanning window. After the improvement, the amplitude analysis will be retained, and the phase analysis part will be removed. Then three adjacent points in the spectrum will be polynomial transformed, so that the interference between harmonics can be Further reduction, the improved FFT algorithm not only has higher accuracy, but also faster operation. However, the value of the window function at the boundary is usually very small. If it collides with the truncated signal, a large amount of information data will usually be lost. This situation is very unfavorable for harmonic detection. In order to reduce the loss of data, the data needs to be overlapped and optimized during sampling to ensure that the error is within a controllable range. The Hanning window function has obvious advantages in overlapping and optimizing data. The resolution of the Hanning self-convolution window is mainly affected by the width of the main lobe, and the two are in anti-correlation. The larger the width of the main lobe, the lower the resolution [6]. However, the leakage of the Hanning self-convolution window is positively correlated with the width of the side lobe. The greater the width of the side lobe, the more serious the leakage. At the same time, studies have found that the side-lobe attenuation rate has relatively strong suppression of spectrum leakage. Therefore, when considering how to reduce spectrum leakage and fence effects, the side-lobe attenuation rate, main lobe width and peak level attenuation parameters must be considered the main factor.

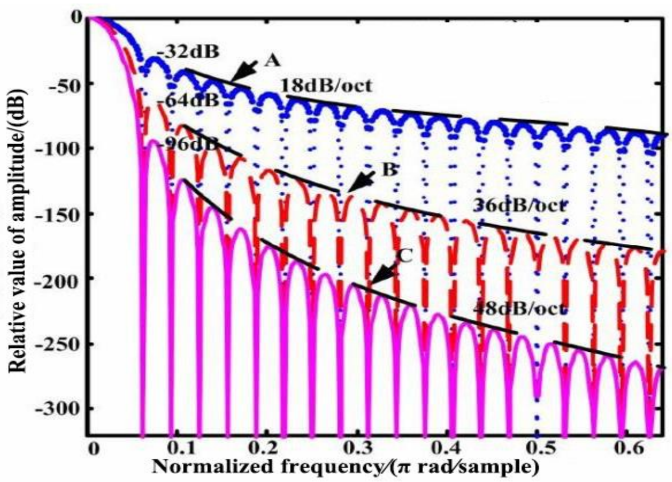

Figure (1). Amplitude-frequency characteristics of self-convolution window

A:Hunning window，B:Second-order hunning self-convolution window，

C:Third-order hunning self-convolution window

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The resolution of the window function is mainly affected by the width of the main lobe, while the suppression of spectrum leakage mainly depends on the two parameters of decay speed and peak level. Therefore, it is necessary to study the characteristics of the main lobe and side lobes of the window function. It can be clearly seen from Figure (1) that the more window functions used for FFT, the better the suppression of spectrum leakage.

5. Algorithm verification

Because the frequency of the grid changes with time, the sampling data cannot be synchronized. Suppose the actual harmonic frequency of the current is shown in formula (1-1):

$$f_m = (k_m + \Delta k_m)\Delta f \qquad (1-1)$$

Among them, $\Delta f = f_s / N$ △km∈(0,1), f_s is the sampling frequency, and N is the number of sampling points, so the harmonic signal can be represented by the form shown in formula (1-2):

$$X_H(k) = \frac{B}{\sigma(\sigma^2 - 1)} \qquad (1-2)$$

Among them, $\sigma = k - k_m - \Delta k_m$ This paper improves and optimizes the Hanning window Fourier algorithm to perform polynomial transformation at three adjacent points in the frequency spectrum, which largely suppresses the interference between harmonics and makes the detection the accuracy is improved, and the new spectrum signal shown in formula (1-3) is obtained:

$$X_{H-3}(k) = aX_H(k) + b[X_H(K+1) + X_H(K-1)] \qquad (1-3)$$

At the same time, the attenuation law can be obtained as shown in formula (1-4):

$$X_{H-3}(k) = \frac{B}{\sigma(\sigma^2 - 1)(\sigma^2 - 4)} \qquad (1-4)$$

Combining equations (1-3) with equations (1-4) can immediately solve for a and b. Therefore, when performing asynchronous sampling, the magnitude of the k-th spectral line amplitude is $|X_H(k)|$. at this time, $k = k_m$ or $k = k_{m+1}$, the spectral line takes the maximum value, and the attenuation speed of other amplitudes is $1/|\sigma(\sigma^2 - 1)|$. Therefore, in order to improve measurement accuracy and reduce spectrum leakage, the amplitude attenuation outside the main frequency must be accelerated to avoid interference between harmonics. Given a known signal with a signal length of 500:

y=20sin x+6sin(3x)+3sin(5x)+sin(7x) 0＜x＜0.1s T =0.02s

Figure (2) shows the signal spectrum analysis of the FFT algorithm, the windowed FFT algorithm and the improved windowed FFT algorithm in this paper under the standard frequency of 60Hz. It can be clearly seen from the simulation results that the spectrum leakage effects of FFT, windowed FFT and improved windowed FFT are successively improved, which certainly suppresses the interference between harmonics.

When the optimized and improved algorithm is used in the harmonic detection and analysis, the Hanning window is added to the signal first, and then the Fourier transform is performed to obtain the spectrum sequence $|X_H(k)|$, and then the polynomial transform is used to obtain $|X_{H-3}(k)|$, So that the two spectral lines at the harmonic frequency point with the largest amplitude, after interpolation calculation, it is found that the actual harmonic frequency point has an offset of ΔK_m compared with other discrete spectrum integer points. ΔK_m for correction. The calibration steps mainly include the following steps:

(1) The value of km is determined by searching the main value spectrum. The rated frequency f0 is taken as 60 Hz, and the maximum amplitude spectrum line and its vicinity are searched, and the relatively small value is taken.

(2) The amplitude ratio am is calculated as follows:

ISSN: 2414-1895 DOI: 10.6919/ICJE.202012_6(12).0024

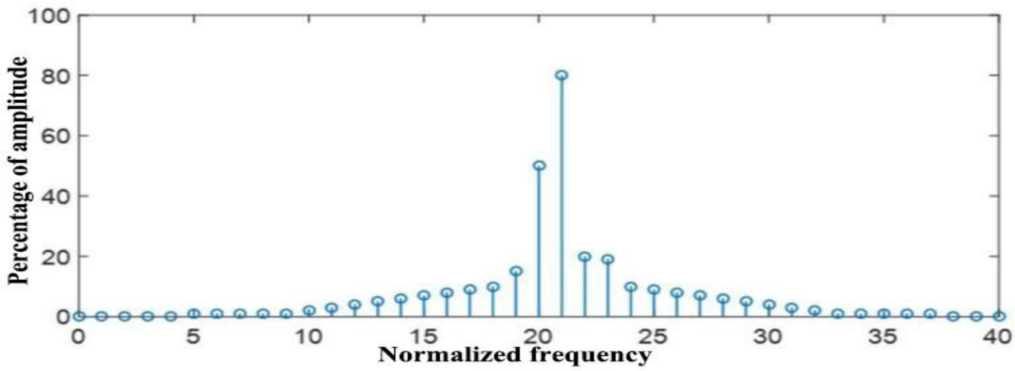
$$a_m = \frac{|X_{H-3}(k_m)|}{|X_{H-3}(k_m+1)|} \tag{1-5}$$

(3) Calculate the value of the offset Δk_m as follows:

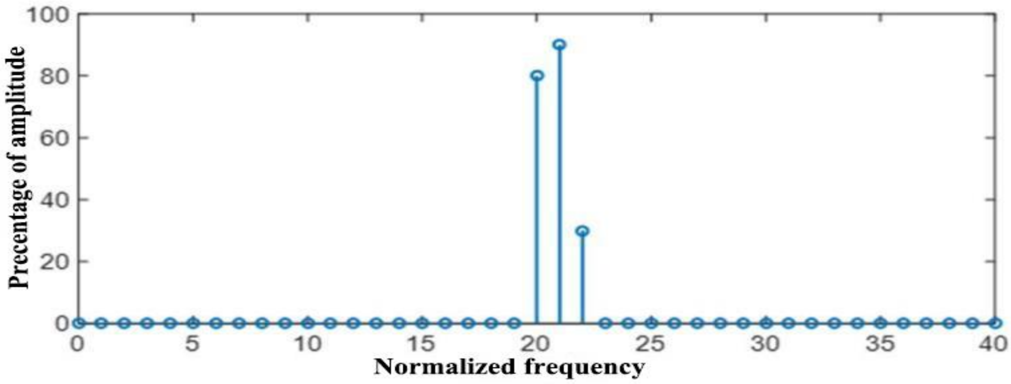
$$\Delta K_m = \frac{4-3am}{1+am} \tag{1-6}$$

(4) Correct the harmonic parameters as shown below:

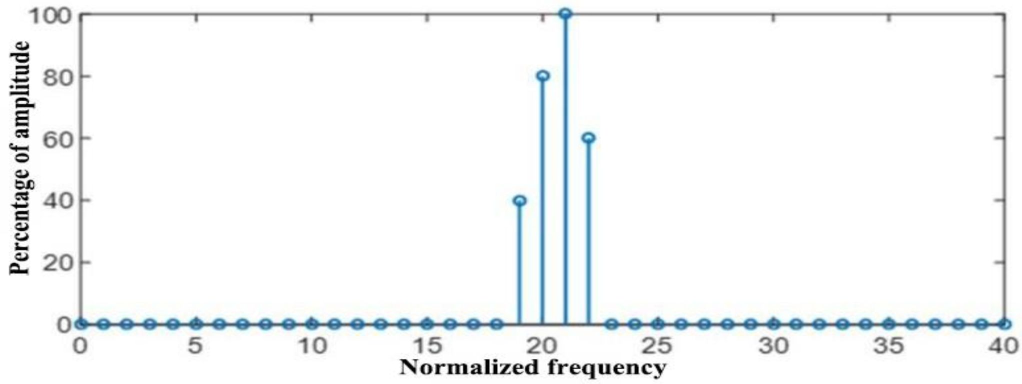
$$X_{H-3}(k_m) = \left|\frac{1}{\Delta K_m(\Delta K_m^2-4)}\right| \bullet \frac{NA_m}{4\pi}\sin(\pi \bullet K_m)e^{j(\varphi+\pi\Delta K_m)}$$
$$\varphi = phase(X_{H-3}(K_m)) - \pi\Delta K_m \tag{1-7}$$



(a)



(b)



(c)

Fig2. Spectrum characteristics: (a) FFT algorithm (b) Windowed FFT algorithm (c) Improved FFT algorithm

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The influence of harmonics in the power grid on the fundamental frequency spectrum is relatively small, mainly because the harmonic components in the power grid are much less than the fundamental components, so the detection accuracy of the fundamental frequency is also higher than that of the harmonic frequency. Many [6]. Therefore, the value of the difference coefficient can be determined by the fundamental wave. In the MATLAB simulation software, the windowed FFT algorithm and the improved and optimized windowed FFT algorithm are used to simulate the signal, and the improved windowed FFT algorithm can be found the less improved algorithm has greatly improved the calculation speed and the accuracy of harmonic analysis. The specific results are shown in Table 2-1.

Inject the sinusoidal signals with harmonics of different amplitudes. The signal length is set to 500, as shown in Figures 3 to 5. The accuracy of the two algorithms using these signals in MATLAB Perform simulation verification. Set up three groups of control simulation experiments, the first group is odd-numbered harmonic signals, the second group is even-numbered harmonic signals, and the third group is even-odd mixed-order harmonic signals.

When no noise is added to odd harmonics:

$$y=20\sin x+3\sin(3x)+\sin(5x)+\sin(7x)+\sin(9x) \quad 0<x<0.1s \quad T=0.02s$$

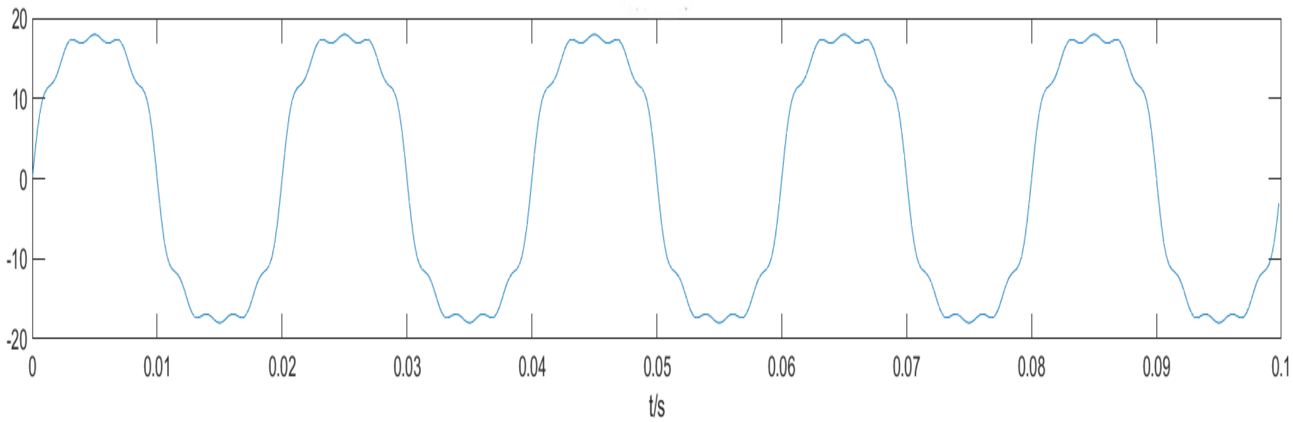

Fig 3. Odd harmonic signal

When no noise is added to even harmonics:

$$y=20\sin x+2\sin(2x)+2\sin(4x)+2\sin(6x)+2\sin(8x) \quad 0<x<0.1s \quad T=0.02s$$

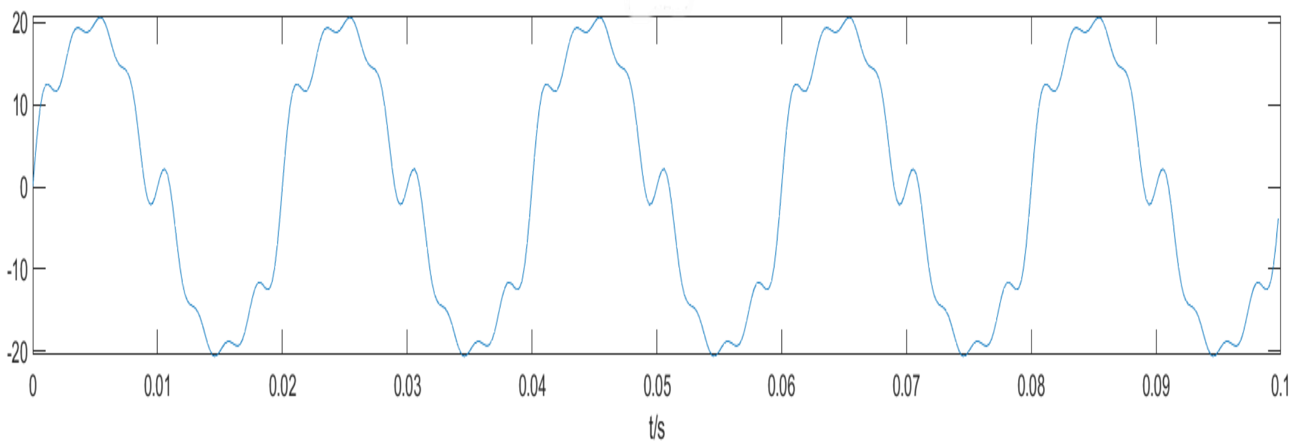

Fig 4. Even harmonic signal

ISSN: 2414-1895 DOI: 10.6919/ICJE.202012_6(12).0024

When no noise is added to the odd and even mixed harmonics:

$$y=20\sin x+3\sin(3x)+\sin(5x)+\sin(7x)+\sin(9x)+2\sin(2x)+2\sin(4x)+2\sin(6x)+2\sin(8x) \quad 0<x<0.1s \quad T=0.02s$$

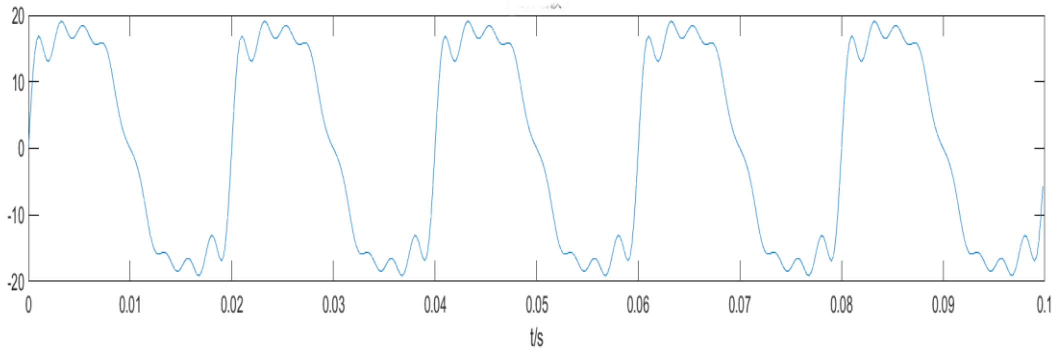

Fig 5. Mixed harmonic signal

Through simulation experiments on odd-order harmonic signals, even-order harmonic signals, and even-odd mixed harmonic signals when no noise is added, the results are shown in the following tables 2-1 to 2-3.

Table 2-1 Odd Number Harmonic Simulation Error

Harmonic order	Standard amplitude	Relative Error of Amplitude in Unimproved Algorithm	Amplitude Relative Error of Improved Algorithm
1	20	1.7E-7	2.8E-8
3	3	1.4E-5	3.1E-6
5	2	5.1E-5	4.9E-6
7	2	5.5E-5	5.5E-6
9	2	6.5E-5	8.5E-6

Table 2-2 Harmonic Simulation Error

Harmonic order	Standard amplitude	Relative Error of Amplitude in Unimproved Algorithm	Amplitude Relative Error of Improved Algorithm
1	20	1.7E-7	2.8E-8
2	2	2.4E-5	4.1E-6
4	1	3.1E-5	6.9E-6
6	1	4.5E-5	7.5E-6
8	1	7.5E-5	9.5E-6

Table 2-3 Simulation Error of Mixed Signal

Harmonic order	Amplitude	Relative Error of Amplitude in Unimproved Algorithm	Amplitude Relative Error of Improved Algorithm
1	20	1.2E-7	2.1E-8
2	2	2.3E-4	1.5E-5
3	3	1.8E-6	1.3E-7
4	1	3.5E-4	6.5E-5
5	2	1.1E-6	3.3E-7
6	1	4.3E-4	3.5E-5
7	2	2.4E-6	5.3E-7
8	1	3.3E-4	1.5E-5
9	2	4.1E-6	4.3E-7

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6. Conclusion

This article introduces the generation and harm of harmonics in marine shore power systems, and expounds the shortcomings of the traditional fast Fourier transform (FFT). Firstly, the improved windowed Fourier transform is used to analyze the harmonics. The detection and analysis have made up for the lack of fence effect and spectrum leakage in the traditional Fourier transform, and improved the detection accuracy of harmonics. Secondly, the polynomial transform scheme is introduced into the improved windowed Fourier transform. Through spectrum analysis, it is found that the improved Hanning window Fourier algorithm has outstanding advantages. Finally, through the simulation detection analysis and comparison of three groups of different signals, it is verified that the improved Hanning window Fourier algorithm has significantly improved the performance of the harmonic detection accuracy.

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