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Distortion Parameters Analysis Method Based on Improved Filtering Algorithm

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Abstract

In order to realize the accurate distortion parameters test of aircraft power supply system, and satisfy the requirement of corresponding equipment in the aircraft, the novel power parameters test system based on improved filtering algorithm is introduced in this paper. The hardware of the test system has the characters of s portable and high-speed data acquisition and processing, and the software parts utilize the software Labwindows/CVI as exploitation software, and adopt the pre-processing technique and adding filtering algorithm. Compare with the traditional filtering algorithm, the test system adopted improved filtering algorithm can help to increase the test accuracy. The application shows that the test system with improved filtering algorithm can realize the accurate test results, and reach to the design requirements.

Keywords*: power supply system, data analyzing and processing, Labwindows/CVI; filtering algorithm*

1. Introduction

The power system, include the aircraft power system and the general industrial power system, is very important, and its performance will affect the quality of power supply system. With the development of science and technology, more and more advanced aircraft equipment, which are made of non-linear loads, is widely used, and generate a large number of harmonics. The harmonics and inter-harmonics in aircraft power supply system will produce the AC voltage and DC voltage distortion, and cause serious pollution to aircraft grid, which seriously affect the reliability of aircraft power supply system [1] [2]. With the continuous increase of the inter-harmonic, the integer harmonic analysis based on the conventional DFT (FFT) algorithm will cause large error; the analysis algorithm should be improved in order to acquire accurate analysis. In the aircraft power supply system, the role of the correction of the voltage regulator of the DC generator, DC generator commentator commutation, load changes, and the rectified voltage fluctuations will cause the DC voltage distortion. The reason of the distortion is many, mainly due to non-linear. The AC voltage distortion is caused by the system works including voltage modulation and frequency modulation, except the non-linear load factors. So, the accurate analysis of the harmonics and inter-harmonics is very important in aircraft power supply system, and can provide a basis for decreasing the harmonics and the development of new aircraft [3] [4].

Compared with the general power system, the distortion test for AC or DC aircraft power system has some characters, such as wide distortion spectrum and wide frequency range. In order to realize the accurate test of the correlative parameters, the filtering algorithm is improved, the distortion parameters test method is introduced, and the distortion parameter test system based on Labwindows/CVI, which can satisfy the requirement of the aircraft AC and DC distortion parameters test in the outfield, is introduced in this paper.

2. Test Content

According to the standard GJB181 and GJB181A, the distortion parameters of aircraft power supply system include the distortion DC voltage, DC distortion factor, DC distortion spectrum, AC distortion voltage, AC distortion factor, AC distortion spectrum. In a AC system, AC distortion is the RMS value of the AC waveform exclusive of the fundamental; the ac

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distortion factor is the ratio of the ac distortion to the RMS value of the fundamental component. In a DC system, dc distortion is the RMS value of the alternating voltage component on the dc voltage; the dc distortion factor is the ratio of the dc distortion to the dc steady state voltage. The distortion spectrum quantifies ac distortion or dc distortion in the terms of the amplitude of the each frequency component.

According to the distortion parameters testing requirements of the national military standard, the measured AC voltage distortion waveform, the AC voltage waveform filtered fundamental waveform, are sampled not greater than the largest integer 1s and the sampling frequency of not less than 1MHz, the AC voltage distortion factors can be acquired by equation (1) ,

$$U_{JJ} = \sqrt{\frac{1}{T_w}\sum_{j=1}^{n}(u_{JJj})^2 \cdot \Delta t} \quad (1)$$

Where, U_{JJ} is the RMS value of AC voltage distortion, T_w is the sampling time, u_{JJj} is the instantaneous value of the AC voltage distortion waveform, n is the times of sample, Δt is the time of every samplings. The other parameters will not introduce in this paper.

3. The Improved Data Processing Method

Due to the existence of various kinds of interference, the acquired data may deviate from the true value. Therefore, in order to the sampled data as close as possible to the true value, the pretreatment technique can be used before the data processing. The sampling data pretreatment technique is mainly striking out the singular term sampling data, which is the point with larger error. These points are not truly representative of the actual value of the measured parameter, but occasional dead pixels in the measurement process, These singular points if not removed, will cause the data processing is greatly increased. In order to minimize the data processing error, before data processing, should these singular items removed, and the position of the point to make up a suitable value.

First-order differential equation is expressed as

$$\hat{x}_t = x_{t-1} + (x_{t-1} - x_{t-2}) \quad (2)$$

Where $\hat{x}_t$ is the value of pretreatment, x_{t-1} is the value of first sampling, and x_{t-2} is the value of second sampling. The value of the time t can calculate by the value of the t-1 and t-2 timing projections. Be compared with the actual data values of the time t with the predictive value of the time t, and then determine the time t, the actual data value is singular term. Its judgment criteria for a given error limit, given an error window, if the actual data value of the time t, then $\left|x_t - \hat{x}_t\right| > W$, that this sample value does not meet the normal variation of the singular term. According to the sampling frequency of the data acquisition system, changes in physical characteristics of the decision, general error window size can be decided. In this data processing method, the spikes can be removed when the curve suddenly appear unreasonable spikes. After that, the system will auto-add corresponding data points, which equal to the previous point values, or equal to the predicted point of data points. The flow chart of the pre-processing program is shown in Figure 1.

The hardware anti-jamming measures can reduce the random interference in the test system, not eliminate them completely. So, the test results have some random interference in the actual test. However, when the number of measurements is large enough, its overall obey statistical laws, most random errors follow a normal distribution. In order to overcome the random error, the hardware anti-jamming technique and digital filtering technique are usually used. The digital filter technique usually selects adding windows function after pre-processing the acquired data. This digital filter technique processes the data through a certain calculation procedures, eliminate or weaken the influence of the interference noise, and improve the reliability and precision of the measurement. In this method, the filter design is very important[5].

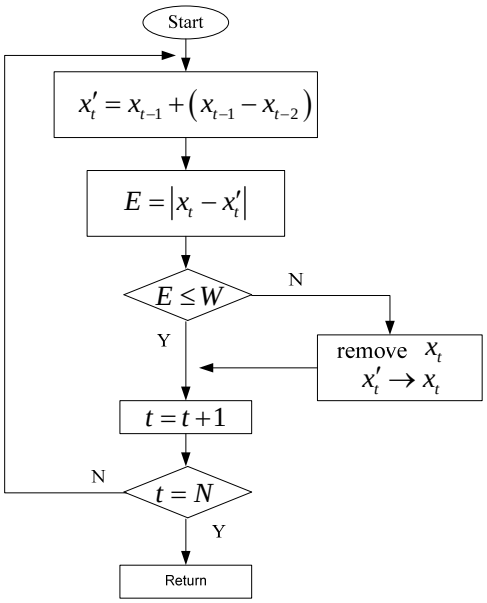

Figure 1. Flow chart of the pre-processing program

The filter with a window function method can divide into steps:

(1) gives the frequency response function $H_d\left(e^{j\omega}\right)$;

(2) according to the allowable width of the transition zone and stop-band attenuation, selects the window function and its length N;

(3)According to the requirement, the unit sampling response function $h_d\left(n\right)$ can be decided,

$$h_d\left(n\right) = \frac{1}{2\pi}\int_{-\pi}^{\pi} H_d\left(e^{j\omega}\right)e^{j\omega n}d\omega \tag{3}$$

(4)The sampling response function of the digital filter $h_d\left(n\right)$ is given

$$h\left(n\right) = h_d\left(n\right)w\left(n\right) \tag{4}$$

(5)The equation is the frequency response function of the filter, and verifies the requirements of technical indicators.

$$H\left(e^{j\omega}\right) = H_d\left(e^{j\omega}\right) * W\left(e^{j\omega}\right) \tag{5}$$

The design method of the window function not only has the advantages, such as structure simple, very practical, but has some disadvantages, such as the cutoff frequency of the pass-band and stop band is difficult to control. The windows functions can select according to the test requirement.

The digital filtering algorithms can realize in the software. For example, the ellipse filtering algorithm and Haining window function are used to analyze the distortion parameter in order to increase the precision and accuracy. The ellipse filtering algorithm let the transient value into coordinate points of two-dimensional coordinates through the appropriate transformation. Because the distribution of these points is a certain law, these points can fit an ellipse.

In order to test the distortion of the power supply system, we can derive the signal frequency, amplitude and phase angle information by solving the elliptic equations. The distortion curve considers the logarithmic coordinates of frequency as abscissa, ranging from 10Hz to 500 KHz. The data with non-fundamental frequency is divided into four frequency bands according to the logarithm coordinates of frequency [1].

The range of the frequency from 10 Hz to 1000Hz named Low frequency band, and its distinguishing ratio is 1Hz; the range of the frequency from 1K Hz to 10KHz named middle-Low frequency band, and its distinguishing ratio is 10Hz; the range of the frequency from 10K Hz to 100KHz named middle-high frequency band, and its distinguishing ratio is 1KHz; the range of the frequency from 100K Hz to 500KHz named high frequency band, and its distinguishing ratio is 5kHz. The four frequency bands processed separately, at last, the data processing results will be calculated the total harmonic content together and draw the spectrum curve [6]. Structure chart of the data processing in frequency band is shown in Figure 2. The data processing block diagram is shown in Figure 3.

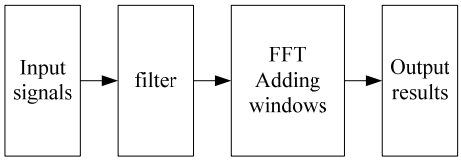

Figure 2. Structure chart of the data processing in frequency band

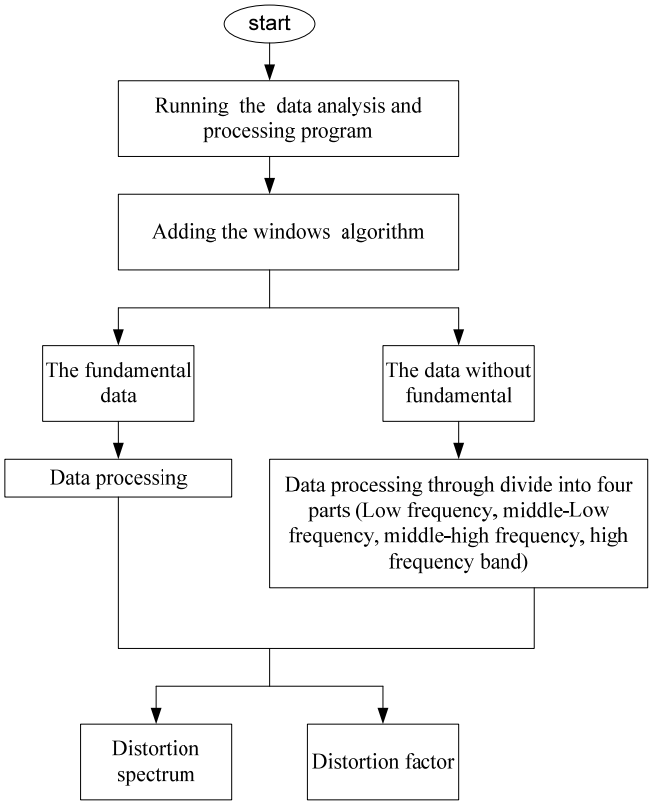

Figure 3. Flow chart of the data analyzing and processing program

4. Test System Design

In order to validate the improved method, the distortion test system is established in this paper. The test system made up of the hardware and the software parts. The hardware parts

include the industrial personal computer, signal conditioning box, data acquisition card, the sensors, the printer, and so on. The software system mainly includes the data acquisition module, the data analyzing and processing module, and so on. The system structure chart of this test system is shown in Figure 4. This distortion test system is used to the distortion parameters testing of certain type aircraft AC or DC power supply system. The system adopts modular design ideas in the software design, each module can run independently.

The hardware system includes IPC, high speed data acquisition card, signal conditioning box, analog output card, RS485 communication card, printer, and so on. IPC is the core of the test system, which can realize the functions, such as the instructions sending or incepting, the data acquisition and processing, and the test results displaying. In order to achieve the data acquisition of the distortion signal, the distortion signal need be filtered before processing. The amplitude of frequency components require very high according to the limit curve of distortion spectrum in GJB181 or GJB181A, so the signal conditioning circuit must be considered in the hardware design. The signal conditioning circuit is divided into two parts after the signal through the relay, one path voltage signal are acquired by the data acquisition card after through the signal conditioning circuit; another path signal of the same voltage signal need be filtered in order to filter out the fundamental and the components of a certain band, and then be sent to the data acquisition card. In this design, two UAF42, which formed a high-pass filter and a low-pass filter, are used in order to realize the band-stop filter, they are connected as a two level band stop filter. The design idea of dc distortion conditioning circuit is similar to the AC distortion conditioning circuit. The conditioning circuit is divided into two parts. The DC voltage signals are acquired by the data acquisition card after through the signal conditioning circuit, and can calculate the dc distortion factor; the same signals will be filtered in order to filter out the dc voltage components, and then be sent to the data acquisition card.

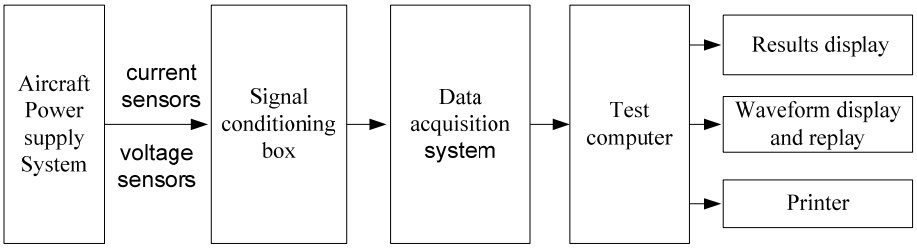

Figure 4. The structure chart of test system

The test system application software [3] adopt the software Labwindows/CVI as the development platform, and mainly made up of test modules, such as the data acquisition module, the data analyzing and processing module, the data waveform display module, the state monitoring module, the report form module and the system help module. The whole system consists of several sub-modules, and the function of data acquisition and processing of each module is realized by calling the sub-modules. The filter windows functions can be transferred by sub-modules [7].

In this test system, the data acquisition module mainly realizes the data acquisition. In this module, the implement of data acquisition need call some sub-modules, such as the channel setup module and the frequency setup module. We can select the test channel by modifying the vale of the sample frequency in the program in back panel. According to GJB181A and GJB181, the sample frequency is the default value that is 1MHz. The setup of the channel parameters need at the beginning of each data acquisition. The data analyzing and processing program is divided into real-time analyzing and analyzing after test. The data analyzing and processing module not only can realize the AC or DC distortion test according to GJB181 or GJB181A, but can save the test data according the needs, and display the real-time waveform at the interface. This module not only can process the data in real-time but can analyze the saved data after the test. In the modules, the waveforms and limit curve will be given in the test results. The data waveform display module can give the waveforms display according the user' needs, the distortion spectrum and the data will be display at the interface.

The state monitoring module mainly used to realize the function of the real-time monitoring. The system help module can help to solve some familiar problems in the using of the software, such as the operation methods, installing approaches, and so on [8] [9]. The flow chart of the application software of the test system is shown in Figure 5.

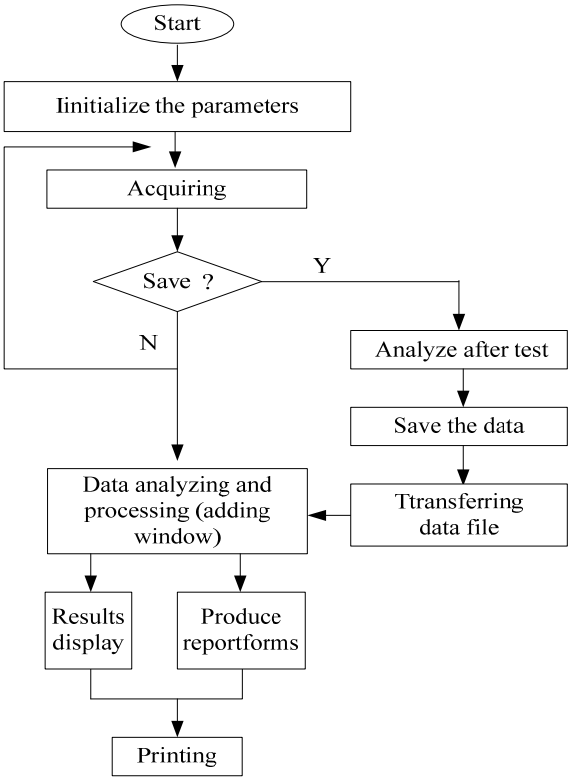

Figure 5. The flow chart of the system design

5. Experiment Results

The test system has been used to the distortion parameter test of the Aircraft ac power supply system in the lab. The system adopted this improved methods can commendably accomplish the corresponding distortion parameters test. The distortion parameter experiment is finished, adding 150A load, the two TRU is worked in full load, the test result is shown in Figure 6, and the AC distortion factor is 0.0159.

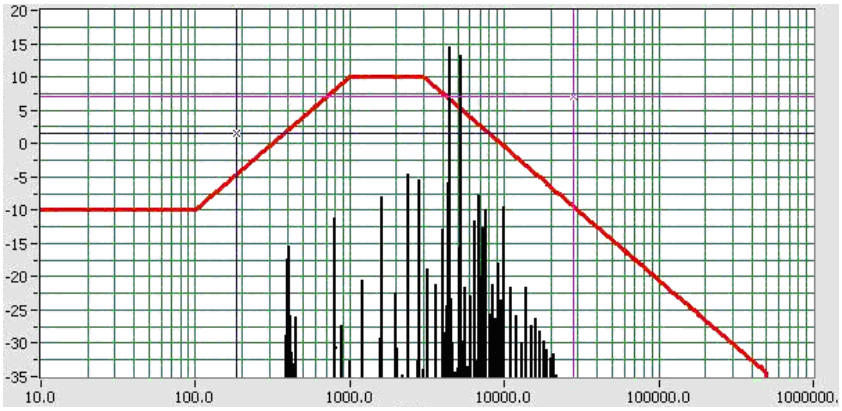

Figure 6. The AC voltage distortion spectrum chart

The test results of this test system have completely samed with the analysis of the spectrum analyzer HP8591E and HP35670A that has been used widely in distortion spectrum test, but the test system adopted the traditional filtering algorithm only can basically samed with it. So, the test system can complete the accurate measurement of the distortion parameters for aircraft power system.

6. Conclusion

The system adopts the ellipse filtering algorithm and adding windows method, reduce the effects of noise interference, and improve the test accuracy. The experiment is shown that the test system with improved filtering algorithm can realize the accurate test results, and increase the test efficiency. The results show that the system precision and accuracy of the test system can reach to the design requirement, and satisfy the requirement of the distortion test, so the improved filter method is feasible.

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