Sensors & Transducers, Vol. 157, Issue 10, October 2013, pp. 212-216

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Study of the Electrical Power Network Harmonic Analysis Algorithm Technology Based on Gradient Blind Signal Separation

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Received: 27 July 2013 /Accepted: 25 September 2013 /Published: 31 October 2013

Abstract: A large amount of electrical power harmonic are injected into the electrical power network because the widely used of nonlinear electrical power load. It brings a great harm to the precision electronic instrument in safety running. This article presented a kind of electrical network harmonic analysis algorithm used for the harmonic signal separation. Through analyzing the harmonic monitor technology at present, using the blind signal separation technology to complete the mixing electrical power system voltage signal separation based on the traditional information maximization blind source separation algorithm and natural gradient algorithm, the simulation result shown that this two algorithm can also realize the instantaneous mixing voltage harmonic signal separation and harmonic analysis monitor. The result expressed that this method can effectively gain a good separation effect with the monitoring spectrum error is less than 1 %. *Copyright © 2013 IFSA.*

Keywords: Electrical network, Harmonic analysis, BSS, Monitor precision, Independent component analysis.

1. Introduction

Now the electrical power network harmonic, electromagnetic interference and the lower power factor are called as three serious electrical power hazards. Therefore, learning the mechanism of harmonic producing and how to compensate it is a very important and significant things to improve the electrical power quality [1]. In addition, with the development of science and technology and the new technology adopted, the computer, electronic instrument control equipment will widely used, it will put forward more and more strict requirements to the power quality.

In recent years, the domestic and international scholars have proposed many extraction methods of the electrical power harmonic analysis and monitor, such as FFT, wavelet transform [2, 3], neutral network [4], and combining multi-algorithm, etc. [5]. But these methods have some limitation. With the development of the independent component analysis technology, blind signal separation technology had been causing the attention in the field of biomedical signal processing. Independent component analysis is a kind of new multidimensional statistical analysis methods, its characteristic is that the individual source signal components can be recovered from the more road observation signal [6].

2. Electrical Power Harmonic Analysis

Electrical power harmonic is a periodic electric sine wave component, the frequency is the integer times of the fundamental frequency, harmonic times is named as the harmonic frequency ratio to the

fundamental frequency. Electrical power harmonic is a kind of disturbance variable, which making the power equipment generate additional loss, reduce the power generation, transmission and electric equipment efficiency. Electrical power harmonic influences the normal work of the electrical equipment, and makes the motor produce mechanical vibration and noise, transformer, capacitor, cable and other equipment is overheating. In addition, it makes the insulation part out of age, metamorphism, which will reduce the service life of equipment.

Electrical power harmonic increases the electrical power grid in the possibility of resonance, especially for capacitor and the series of the reactor, the grid resonance often make burned. And it makes relay protection and automatic device, computer system mis-operation, results in unnecessary interruption of power supply and loss. High precision monitoring instrument can't correct instructions or measurement, which producing the monitor error, or lead to the direct economic losses.

It also interference the nearby communications system, produce the noise and reduce communication quality, even tend to cause the information loss, and damage the communication equipment. Therefore, the harmonic suppression has very important significance, the harmonic detection and analysis is the key of harmonic suppression. This article a kind of current relatively popular blind signal separation algorithm, and used in the harmonic separation and analysis [7].

3. Electrical Power Harmonic Analysis Algorithm

The blind signal separation [8] algorithm of independent component analysis requests the output signal to satisfy the independence character, so, independent component analysis algorithm design is to build a output variables independence target function, and to optimize this function, then to search an optimal separation matrix. At present, a variety of independent component analysis algorithm has been proposed, in which the information maximization independent component analysis blind source separation algorithm is the most representative. The information maximization algorithm is a kind of suitable nonlinear function is introduced in the output, which makes the output information entropy to get maximization [9]. Electrical power harmonic analysis and monitor algorithm principle frame diagram is shown as Fig. 1.

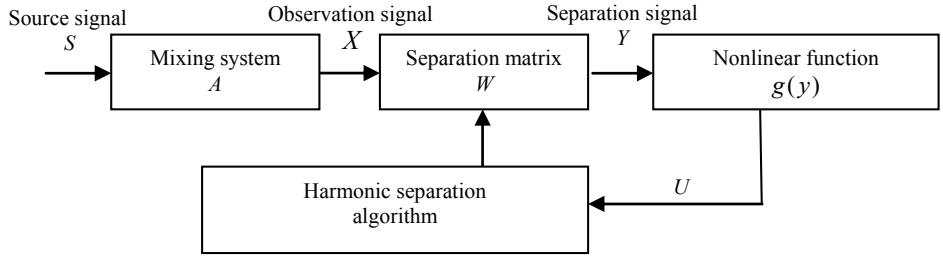


Fig. 1. Harmonic analysis BSS algorithm model.

From the Fig. 1 we can see, the independence criterion to information maximization algorithm is information maximization transmission standard, after the separation matrix W solution, each component y_i of the output result Y is respectively used the nonlinear function g(y) to processing, which makes the output total entropy H(U) achieve the maximum amount, if g(y) is the accumulation of the distribution function for each component y_i

The independent component separation matrix solving process can be described as the type of optimization problem shown in formula (1):

$$\max : H(U)H[g(W_X)] \tag{1}$$

By the entropy change theory,

$$H(U) = H(X) + E[\log | J_x |] \tag{2}$$

From the formula (2) we can see, J_x is the type of Jacobi transformation between x and y. Due to H(x) has nothing to do with W, then we can get through differentiating H(y) to W. By the matrix differential theory, on the type of item 1 is: $(W^T)^{-1}$, the second item is $\sum_{i=1}^{N} \frac{\partial}{\partial W} \log | \frac{\partial y_i}{\partial u_i} |$.

$$\sum_{i=1}^{N} \frac{\partial}{\partial W} \log | \frac{\partial y_i}{\partial u_i} | = \frac{g''(u)}{g'(u)} X^T \tag{3}$$

Making the $\varphi(u)$ as the evaluation function.

$$\varphi(u) = \frac{g''(u)}{g'(u)} X^T \tag{4}$$

From the formula (4), $\varphi(u)$ is a column vector.

$$\varphi(u) = [\frac{g''(u)}{g'(u)}, ..., \frac{g_N''(u_N)}{g_N'(u_N)}]^T \tag{5}$$

Because $\frac{\partial H(Y)}{\partial W} = (W^T)^{-1} - \varphi(u)X^T$, then we can get the random gradient Informax algorithm.

$$\Delta W = \mu[W^{-T} - g(y)x^T] \tag{6}$$

If we right multiply W^TW to the formula, we can get another formula (8) as the bellow type.

$$\Delta W = \mu[I - g(y)y^T]W \tag{7}$$

The formula is just the natural gradient blind separation algorithm basic type. The natural gradient algorithm avoids the complexity of the matrix inversion, and improves the operation efficiency.

The blind source separation algorithm performance usually has the two kinds, one is the similarity coefficient expressed as the similarity degree between the separated signals and the source signal; another kind is crosstalk error expressed as the independence of elements based on the global transfer matrix elements. The crosstalk error expressed the deviation degree between the inverse matrix of the separation matrix **W** and the mixed matrix **A**. The crosstalk error is defined as formula (8)[10].

$$E = \sum_{i=1}^{N}\{(\sum_{i=1}^{N}\frac{|g_{ik}|}{\max_j|g_{ij}|} - 1) + (\sum_{k=1}^{N}\frac{|g_{ki}|}{\max_j|g_{ji}|} - 1)\} \tag{8}$$

As formula (8), $\max_j|g_{ij}|$ is the absolute maximum value of the i^{th} row element. When the separated signal y with the source signal s waveform is completely same, then E=0. In Practice, when E reached 10^{-2} orders magnitude, the algorithm separation performance has been quite good. E is the crosstalk error, E, the smaller the value that the better separation effect of the algorithm.

4. BSS Algorithm Simulation

To prove the blind signal separation algorithm accuracy based on the information maximization algorithm and natural gradient algorithm in the electrical power harmonic analysis, we simulated a group of sine wave, including the basic wave, 2 times harmonic, 4 times harmonic, and 6 times harmonic. The initial simulation signal is shown as Fig. 2.

We blind mixed the four groups of sin-wave signal by using the 4*4 matrix blind mixing after blind mixing, the mixing signal is shown as Fig. 3. We take a nonlinear function y^3, step length is 0.002, and use Information maximization separation algorithm to separate the mixing signal. Before separation, the observation signal has carried out the mean and whiten processing.

From the Fig. 3 we can see, the blind mixing signals are hard to identify their initial condition. If we carry out the spectrum analysis to the observation signal, the result is shown as Fig. 4.

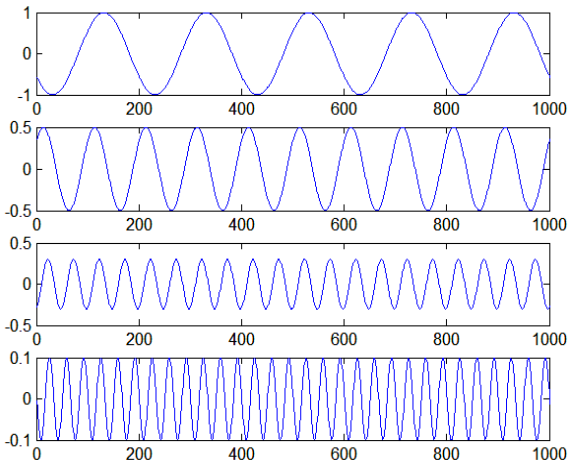


Fig. 2. Initial mixing source signal.

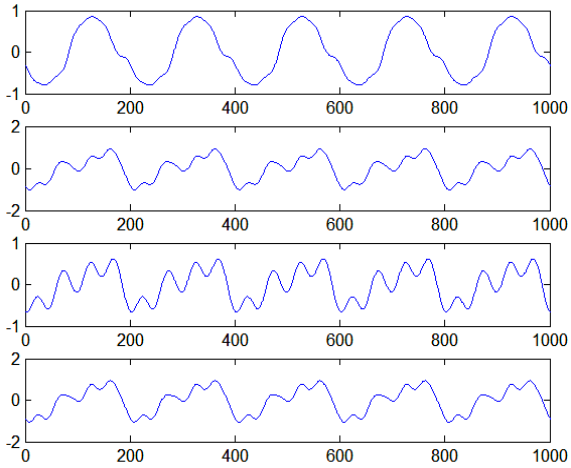


Fig. 3. Observation blind mixing signals.

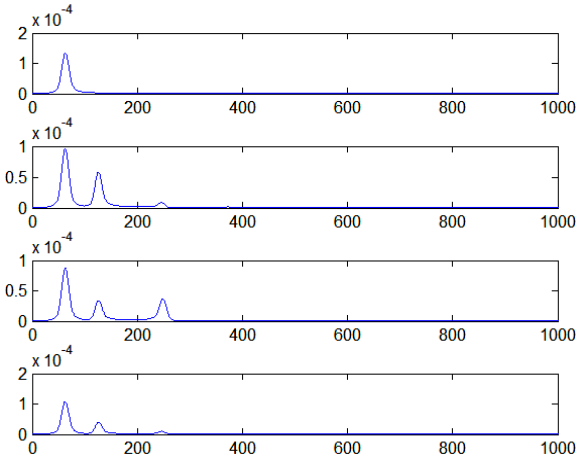


Fig. 4. Spectrum of observation signal.

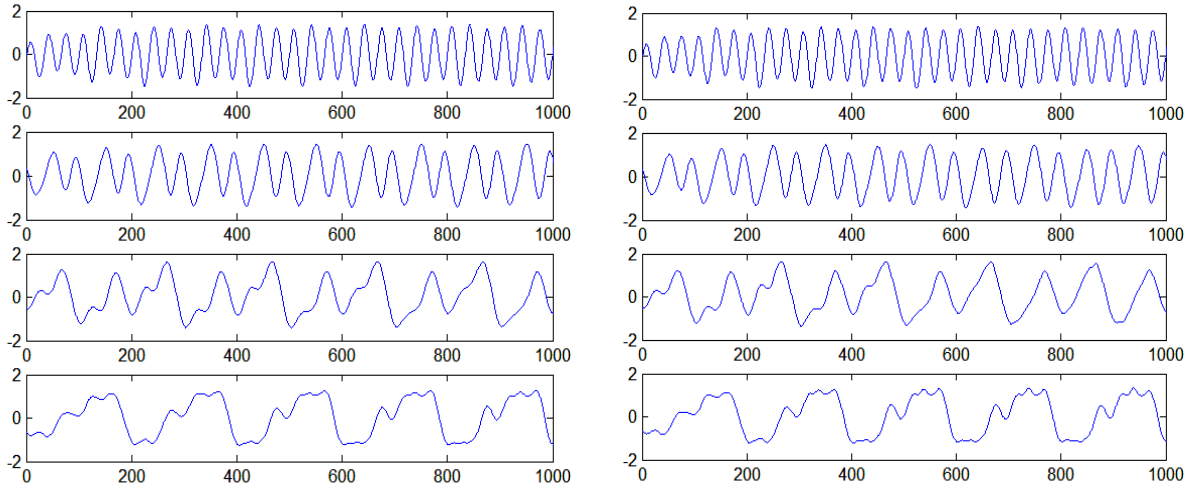
From the Fig. 4, we can not clearly know the frequency character of the initial mixing signal. So, usually we carry out the separation processor to the mixing blind signal, which is easily to find the initial signal mixing relationship. The results of using Information maximization BSS algorithm to separate observation signal are shown as Fig. 5.

From the Fig. 5 we can see, the separation results after using the Information maximization algorithm gained the better effect. we can see the each voltage harmonic component and the noise signal. And we can find the harmonic signal can be effective segregation from the mixing voltage signal.

Through the comparison with the initial signal we can see, signal separation effect is good, and in order to observe the separation precision, we carry out the spectrum analysis, which is shown as Fig. 6.

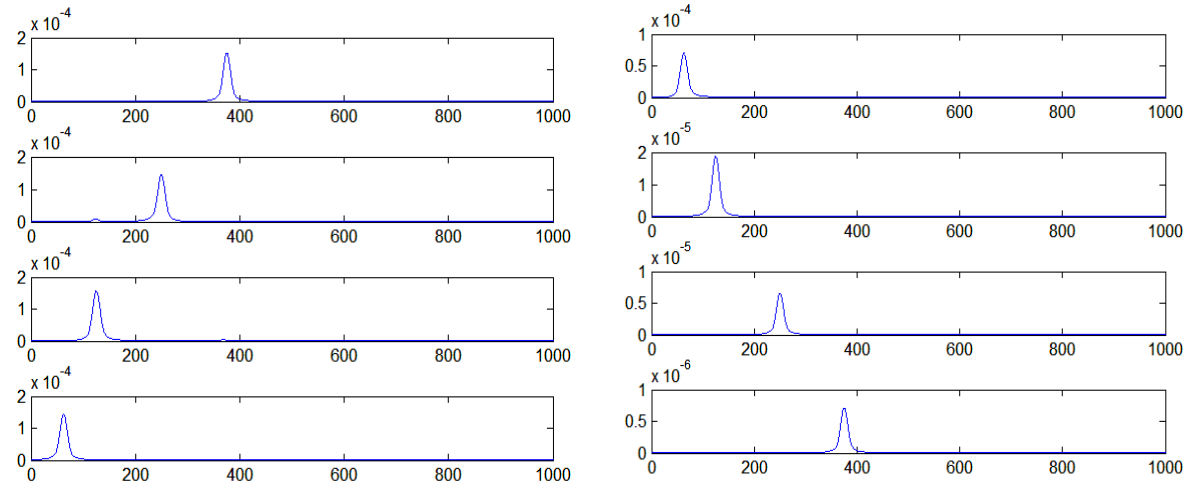
From the Fig. 6 we can see, the initial voltage frequency respectively is 50 Hz, 150 Hz, 250 Hz, 350 Hz. From the two kind of separation algorithm result we can see, separated result by Information maximization algorithm and natural gradient algorithm this paper presented has little error comparing with the initial source signal, and the maximum absolution value is little, which proved this algorithm has high separation precision. In order to observe the convergence speed and steady-state error to the two algorithms, we carry out the crosstalk error analysis to these two algorithms.

The result is shown as Fig. 7. From the Fig. 7 we can see, the Informax algorithm is slower to realize algorithm convergence than the natural gradient algorithm, but the steady-state error is larger than the natural gradient, which proves the algorithm accuracy in theory analysis.



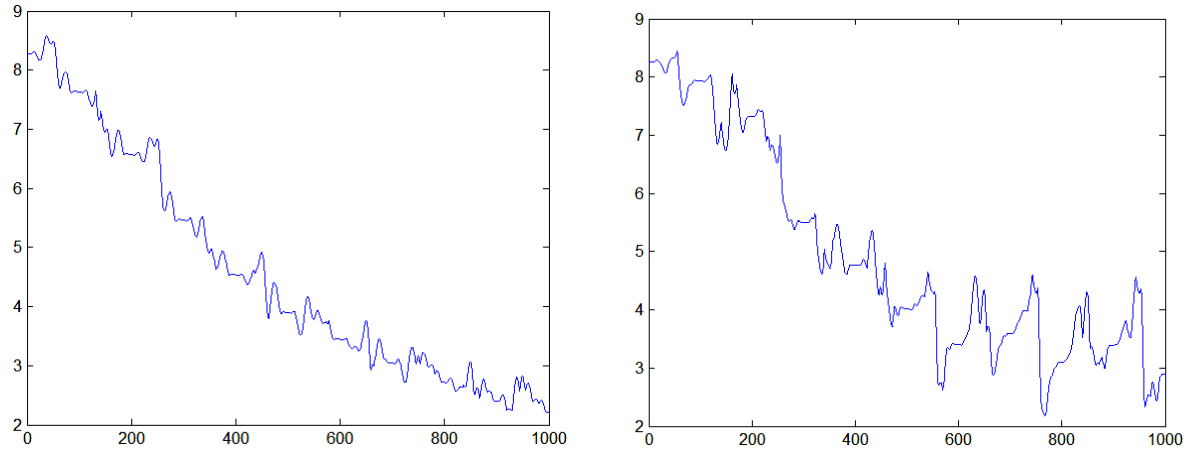
(a) Informax algorithm. (b) Natural gradient algorithm.

Fig. 5. Separation signal based on BSS algorithm.



(a) Informax algorithm. (b) Natural gradient algorithm.

Fig. 6. Spectrum of separation signal based on BSS algorithm.



(a) Informax algorithm.

(b) Natural gradient algorithm.

Fig. 7. The crosstalk error based on BSS algorithm.

5. Conclusions

This paper mainly discussed the blind mixing voltage harmonic signals separation technology, introduced the model of the independent component analysis algorithm and the implementation methods of Information maximization algorithm, studied the establishment of the objective function, and the realization of the algorithm. Through the separation experiments of voltage harmonic blind mixing, we use the Information maximization algorithm to separate the basic wave signal and each times harmonic in higher precision, which proved the accuracy of the blind signal separation algorithm.

Acknowledgments

This paper is supported by the Science and Technology Development Plan Projects of Henan Province in 2013. (No. 132102210441).

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