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A novel Technique for Electrical Power System Harmonics Identification Based on Blind Source Extraction (BSE)

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Abstract

Harmonics in electric power system cause major problems due to non-linearity of some huge loads connected to the distribution network and other sources of harmonics. The massive utilization of power electronic devices with the excessive and rapid growth in applications of converters generate multi harmonic types with different frequencies. So the problems of harmonics existence in the power system and how to calculate, isolate and reduce its impact are accounted of a great challenge for the electrical power networks engineers, whereas obtaining the modeling of the elements of the interconnected power systems sometimes represents another complicated problem facing these engineers. Blind Source Extraction (BSE) or Blind Source Separation (BSS) techniques are used to extract useful information from mixture without knowing any information about the mixing system, then eliminating these harmful signals in power system for example. In this paper an effective algorithm is proposed based on mixing between two blind source extraction techniques to detect the independent sources from mixture. This novel approach algorithm called modified blind source extraction technique. The Interference to Signal Ratio (ISR) measure is used to check the validity of the proposed work. Application of this effective and novel algorithm is used here to solve harmonic problems in electrical power system distribution. The obtained results are comparable effective enhancements in the fundamental pure signal.

Keywords: Blind Source Separation (BSS), Blind Source Extraction (BSE), power system harmonics, Interference to Signal Ratio (ISR).

INTRODUCTION

All Electric power system (generation, transmission and distribution) are operating with alternate current and voltage, (50 or 60)Hz and sinusoidal waveform shapes. Maintaining pure sinusoidal waveform shape of current and voltage, however is very difficult in this dynamic system due to nonlinear, temporally switching and different varity types of loads, these will distort the operating voltages and currents waveforms of the electrical power system [1]. These distorted waveforms called harmonics. Harmonics can be defined as periodic distorted waveform with integer multiples frequencies with respect to fundamental one . Harmonics have a fatal and effective impacts in any electrical power system, especially, during recent decades, so the methods of harmonic mitigation, separation and analysis are very essential and necessary. Many effective methods have been applied to solve the harmonics existence problems, like the harmonic filters which include passive and active types [2]. The reliable passive filter design requires an essential knowledge about the impedance of the harmonic system which is related to its variations throughout the operating time in order to avoiding a resonance condition creation, which effect on the stabilization of the electric al power system. Also, active filters require a sufficient knowledge about the impedance of the harmonic system to ensure reliable and stable operation of the controller. For all these effective and important reasons , the identifications, extractions, separations and measurements of harmonics impedances have become very important issue in power system for mitigations and harmonics analysis. Harmonic source identifications in any electrical power system have been accounted as a challenging task for many decades of years [3]. Many conventional and intelligent techniques have been used and applied to measure and determine the customer and the responsibility of systems for distortion of harmonics. The synchronized measurements method in multiple points in electrical power network accounted as difficult and more expensive task. Many solutions technique methods and practical approaches which are based on data measurements at Point of the Common Coupling or (PCC) between electrical systems and the customer have been used. In spite of all of that, there are few references and works dealing with determination contribution of harmonics at PCC, none of them are widely applied in practice [4]. Blind Source Separation (BSS) or Blind Source Extraction (BSE) is one of the powerful technique in harmonics identification and separation, conjointly referred to unsupervised algorithm in signal separation field. BSE algorithms estimate the signals of sources from observed mixture. The word (blind) in blind source separation technique emphasizes between the way that sources are mixed and the source signals. Wide range of applications enclosed by blind source extraction technique such as in telecommunication, neurophysiological signal, medical signal processing, speech signal, image processing and harmonics separation [5, 6]. BSE is used to separate and extract the underlying signals from the received signals without or with little information about the original sources [7]. Blind technique was born in the 1980s; this technique is used firstly to design adaptive equalizer for digital communication system. In 1982; the formulation of source separation was prepared by B. Ans, J. Heranlt, and C. Jutten [8]. The blind source separation problem was formulated around 1984 [7] using higher-order moments for matrix approximation and then other similar studies on this field was developed to describe theoretical fundamentals as in [9]. The fast BSS algorithm was developed for independent component analysis [10]. BSS techniques have gained considerable attention in academic and industry field and significant developments have been occurred in BSS applications, especially, in medical signal processing, pattern analysis, wireless communication system, image recognition, remote sensing, data mining, and multimedia etc. [11-13]. During the last decades, wide research area are opened when using BSS technique to analyze the medical signals, particularly in brain signal, whereby the BSS used as a signal processing tool to reject the artifacts and clean the brain data. BSS techniques have also been applied in radio communication system, to present a multimode wireless communication receiving system, and detect different types of communication signals for different wireless channel conditions [14]. Further applications can be found in [15-19]. In this present work BSS and BSE techniques are utilized here to solve the major problem in power system distribution grid which are harmonics identification, extraction, analysis, mitigation and elimination.

BSE AND ITS APPLICATION IN POWER SYSTEM

A. BSE Technique

Define The BSS or BSE technique algorithm can be formulated as a mathematical model as shown in figure 1 [20, 21].

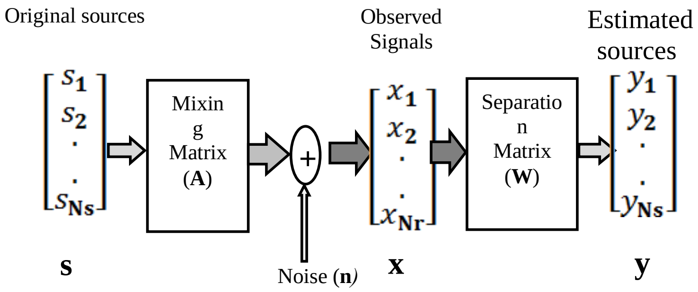

Figure.1. BSS schematic diagram

A set of original sources s(t) = [s_1(t), s_2(t)…s_{Ns}(t)]T, mixed randomly by mixing matrix A to produce mixtures x (t) = [x_1(t), x_2(t)…x_{Nr}(t)]T; the mathematical model of BSS without noise is [22]:

$$\begin{bmatrix} x_1(t) \\ x_2(t) \\ \vdots \\ x_{Nr}(t) \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1Ns} \\ a_{21} & a_{22} & \cdots & a_{2Ns} \\ \vdots & \vdots & \cdots & \vdots \\ a_{No1} & a_{No2} & \cdots & a_{NrNs} \end{bmatrix} \begin{bmatrix} s_1(t) \\ s_2(t) \\ \vdots \\ s_{Ns}(t) \end{bmatrix} \quad (1)$$

The main goal of BSS algorithm is to estimate the original sources by estimate the mixing matrix A or its inverse, which named un-mixing matrix W (ideally equal to A^{-1}) where:

$$\mathbf{s}(t) = \mathbf{W}\,\mathbf{x}(t) \quad (2)$$

System with noise is:

$$\mathbf{x}(t) = \mathbf{A}\mathbf{s}(t) + \mathbf{n} \quad (3)$$
$$\mathbf{n} = [n_1(t), n_2(t) \ldots n_s(t)]^T$$

B. System Model

As previously specified, the aim of BSS is to recover unknown sources with the observations. The purpose of this part is to illustrate the capability of BSS algorithms to separate signals from mixtures. Figure 2 illustrate the complete system model.

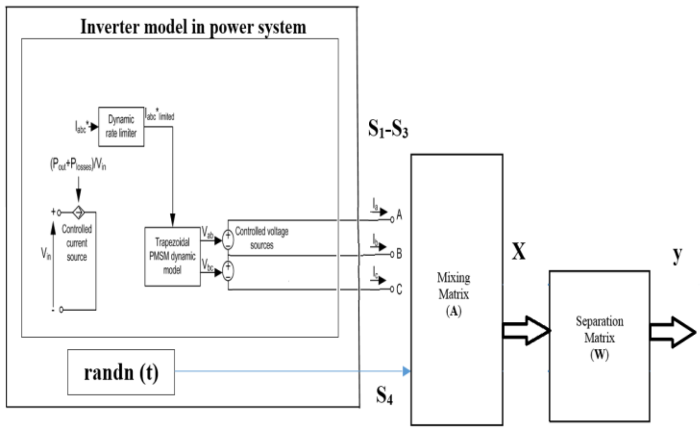

Figure 2. The complete system model

S_1= phase R; S_2= phase S; S_3= phase T; S_4= thermal noise.
A set of original sources s(t) = [s_1(t), s_2 (t)]T, mixed randomly by mixing matrix A which represented here to produce mixtures x(t) = [x_1(t), x_2(t)…x_{Nr}(t)] T.

PROPOSED ALGORITHM : MODIFIED BLIND SOURCE EXTRACTION

An algorithm called modified blind source separation technique is proposed to detect and extract different sources from their mixture. It's based on the joint between Fast independent component analysis and JADE technique. The proposed algorithm consists of two steps as shown in figure 3.
Step 1: Running the EFICA (Fast Indep. Comp. Anay.) technique until convergence.
Step 2: Refinement: running JADE technique (Joint Approx. Diagon. of Eigen-matrices) to get separated signals.
In step 1; The main goal of BSS techniques is to convert a multichannel signal X to separated independent components. Actually, the separated components are not fully statically independent, but they are as independent as possible [23].
In step 2; (JADE) Algorithm is used as a refinement process to the coefficients of the separating matrix W Initial (which obtained from step 1) [24]. Same experiment are taken from [25], the measured signals of the voltage or current in many applications are very sensitive with harmonic signals through a current or voltage sensors or transducer. From reference [25] the LTS-25NP was selected as the transducer for the current. Some harmonics are produced and can be separated by the different types of BSS algorithms because these signals are

independent component. Also many applications have separate harmonics.

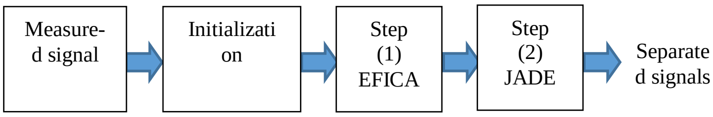

Figure 3. Block diagram of the proposed algorithm

RESULTS

The main goal of this section is to demonstrate the capability of the proposed work to separate the original signals from mixture of signals and harmonics due to power electronic converters applications in the electric power system distribution.

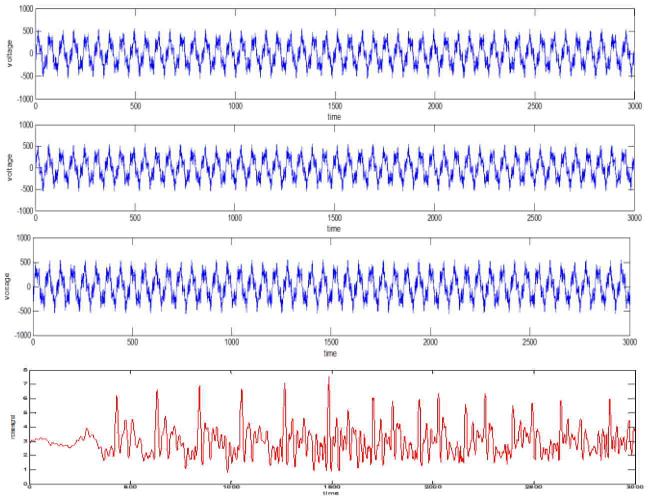

Figure 4. Observed sources (S_1= R , S_2=S, S_3=T, & Noise (Auxiliary Harmonics))

The observed signals are demonstrated in figure 4. These signals are produced by passing the original signals through mixture model, while figure. 5 illustrate the Mixtures signals (X_1, X_2, X_3, & X_4).

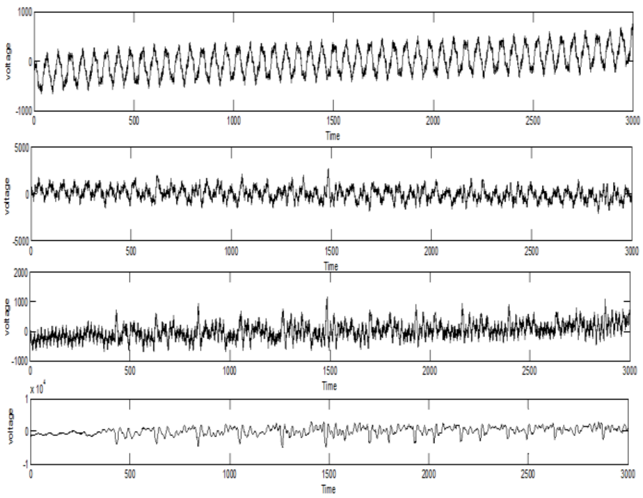

Figure 5. Mixtures signals (X_1, X_2, X_3, & X_4)

the recovered signals by the proposed algorithm are shown in figure 6, where the first three signals represent the 3 phase currents or voltages (R, S, and T phases),, the 4th signal represents the thermal noise signal (auxiliary harmonics) and the last three represent the harmonic signals, from this figure the pure three phase signals are extracted by the proposed techniques and separated from its harmonic signals and thermal noise , as shown in figure 6.

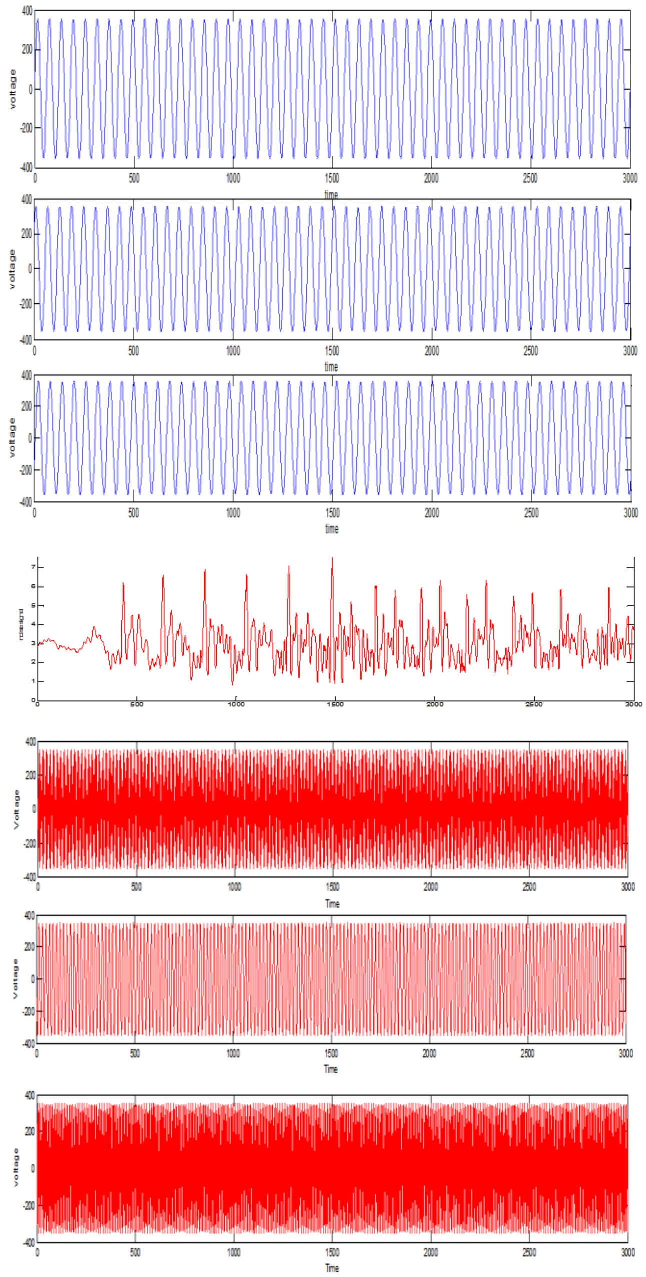

Figure 6. Recovered signals

Visual inspection of the signal separation confirms that proposed work effectively extract the original sources. However, another measure based on Interference to Signal Ratio (ISR) is used to measure the performance of the proposed algorithms[26]:

$$ISR_i = 10\log\frac{E[(s_i(k)-y_i(k))^2]}{E[(s_i(k))^2]}$$

Where s(k) is the input signal and y(k) is the extracted signal from BSS technique; the result of the separating process is better whatever the ISR measure be less as shown in table 1. The results which obtained by proposed technique is clearly better than other BSS techniques, where the best average value of ISR measure for the proposed method is -42.55 dB (which indicated by bold text) and the worst value is obtained by JADE technique about -30.29 dB as shown in the table 1.

Table 1: Comparison of ISR values for different BSS algorithms.

Interference Signal Ratio (ISR) for recovering signals	**BSS Methods**		
	JADE	**EFICA**	**Proposed**
y_1	-26.11	-27.17	-44.71
y_2	-28.19	-54.22	-46.13
y_3	-26.17	-24.18	-33.16
y_4	-28.18	-26.29	-37.87
y_5	-33.94	-39.23	-54.28
y_6	-51.28	-44.93	-56.14
y_7	-19.29	-28.21	-28.25
y_8	-29.18	-39.12	-39.87
ISR Mean	-30.29	35.41	**-42.55**

CONCLUSION

It is found that blind source extraction and separation techniques are very useful in the area of power system analysis and its applications. The novel technique that used mixing algorithm between JADE and EFICA is proposed and applied to the different mixing signals to extract a wide variety of signal from there mixture due to the applications of power electronic converters in power system distribution. There is a big difference in enhancement results between proposed work and original BSS algorithms. The proposed algorithm is based on the hybridization between two BSS techniques. The mean value of ISR measure demonstrates that the performance of the proposed algorithm has very good enhancement with respect to the performance of the JADE and EFICA algorithms as shown in the simulation results.

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