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A Novel Method of Classifying Power Quality Disturbances

T. Murali Krishna[1] **Dr.K.S.R.Anjaneyulu[2]**
Dr. P. Ram Kishore Kumar Reddy[3]

[1]Asst. Prof., Dept. of EEE, CBIT, Gandipet, Hyderabad,
tmurali5@gmail.com
[2]Professor, Dept. of EEE, JNTUA,Anatapur,
ksralu@yahoo.co.uk
[3]Asso.Prof., Dept. of EEE, MGIT, Hyderabad,
prkkreddy252@gmail.com

ABSRACT

This paper presents a novel method of feature extraction that characterizes power quality disturbances. Different power quality problems like voltage sag, voltage swell, harmonics and inter-harmonics are developed in MATLAB environment. For feature extraction, a multi resolution analysis technique is proposed. The proposed wavelet transform localizes different power quality problems accurately. The wavelet co-efficients represents the feature extraction of various power quality disturbances. The approximate co-efficients represent the power frequency signal and the detailed coefficients tell us the time localizing information about the variation of the signal.

Keywords— Signal Processing, Multi Resolution Analysis, wavelet Transform, Power quality.

INTRODUCTION

Advent of power electronic controlled loads such as diagnostic systems, micro processor/controller based systems, logical controller based systems has increased power quality problems. Unfortunately semiconductor based systems are mostly non-linear in nature introducing power quality disturbances in the supply system. Lack of quality in power may cause several problems such as malfunction, instabilities, short lifetime, and so on. Therefore it is required not only to identify the power quality problems but also to mitigate power quality disturbances. Transients are one of the power quality problems usually experienced by power system equipment. These are due to internal and external disturbances. Usually the internal disturbances are due to faults in the system, sudden switching operation, whereas external disturbances are mainly due to lighting strokes. Generally transients are of short duration which reduces the life time of electrical equipments and mal operation of power system. Because of short duration characteristics of the transients, they are difficult to detect. In order to avoid mal operation of the equipments, these transients are required to be identified and subsequently classified by using localization techniques.

SIGNAL PROCESSING

The amplitude of the waveform provides information about the potential for damage to the affected equipment. The frequency content informs how the events may couple to other circuits. To obtain the frequency information or amplitude information or both from the disturbed signal, it is required to process the signal which is in time domain. To obtain the hidden information from the raw signal, mathematical transforms are quite necessary to assess frequency/amplitude information. The mathematical transforms such as Fourier Transform (FT), Fast Fourier Transform (FFT), and Short Time Fourier Transform (STFT) are quite useful to characterize the raw signal depending on its nature.

There are several signal processing techniques used for the analysis of power quality disturbances. The conventional mathematical transforms such as Fourier Transform (FT), Discrete Fourier Transform (DFT) and Short Time Fourier Transform (STFT) have been proposed. Fourier transform decomposes the signal into a sum of sinusoidal signals of different frequencies i.e. it gives information regarding frequency versus magnitude. But it doesn't give information about the time of occurrence of the frequency content of the signal[1]. Hence FT is suitable for the analysis of disturbances which are of stationary in nature.

The STFT represents the time-frequency based views of a signal. It provides the information about both when and at what frequencies a signal event occurs. However, it can only provide this information with limited precision, and that precision is determined by the size of the window. The main drawback of STFT is that once a particular size for the time window is chosen, that window is the same for all frequencies.

Many signals require a more flexible approach where variable window size is used to determine more accurately either time or frequency. But the objective of processing the non-stationary signal is to obtain not only the frequency versus magnitude but also the instants at which they exist along with variable windowing technique. This can be achieved by wavelet transform which provides simultaneous representation of time, frequency and magnitude of the measured signal[2]. Therefore wavelet transform will play a significant role to identify and characterize the power quality disturbance accurately.

WAVELET TRANSFORM

Wavelet Theory is the mathematics associated with building a model for a non-stationary signal, with a set of components that are small waves, called wavelets. Informally, a wavelet is a short-term duration wave. These functions have been proposed in connection with the analysis of signals, primarily transients in a wide range of applications. The basic concept of wavelet analysis is the use of a wavelet as a Kernal function in integral transforms and in series expansions like the sinusoid in Fourier analysis.

The wavelet transform or wavelet analysis is probably the most recent solution to overcome the shortcomings of the Fourier transform [3]. In the wavelet analysis the use of a fully scalable modulated window solves the signal-cutting problem. The window is shifted along the signal and for every position the spectrum is calculated. Then this process is repeated many times with a slightly shorter (or longer) window for every new cycle. In the end the result will be a collection of time representation of the signal, all with different resolutions [4].

Wavelet analysis overcomes the limitations of Fourier methods by employing analyzing functions that are local both in time and frequency. Unlike Fourier analysis, which uses one basis function, wavelet analysis relies on wavelets of rather wide functional form. The wavelet functions are generated in the form of translation and dilation of fixed function. The basis wavelet is termed as a mother wavelet.

The continuous wavelet transform is defined as follows

$$CWT(b, a) = \int f(t)\, \psi^{*}_{b,a}(t)\, dt$$

Where * denotes complex conjugation. This equation show how a function $f(t)$ is decomposed into a set of basis functions $\psi_{b,a}(t)$, called the wavelet. The variables a and b, scale and translation, are the new dimensions after the wavelet transform.The wavelet analysis supports multi-level decomposition of the signal to obtain approximations and details of the original signal.

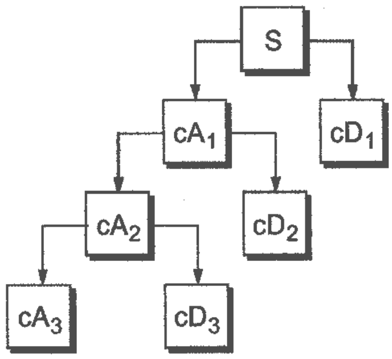

Fig.1 Multi resolutional decomposition of the signal

The decomposition process can be iterated, with successive approximations being decomposed in turn, so that one signal is broken down into many lower-resolution components. This is called the wavelet decomposition tree, which yields valuable information[5].

The approximations are the high-scale, low-frequency components of the signal. The details are the low-scale, high-frequency components. The filtering process, at its most basic level, looks like in the Fig. 1. Since the analysis process is iterative, in theory, it can be continued indefinitely. In reality, the decomposition can proceed only until individual details consist of a single sample or pixel. In practice, we will select a suitable number of levels based on the nature of the signal.

CHARACTERIZATION OF POWER QUALITY DISTURBANCES

To perform the Wavelet Analysis on the signals, Daubechies wavelet '4' and the analysis is performed up to 5^{th} level of decomposition. For this analysis, the "Wavelet Toolbox" in MATLAB is utilized. The process of analyzing the signals using the Wavelet Toolbox involves following steps:

Step-1: The magnitude of the signals is stored as one-dimensional vector in MATLAB to generate the signal of format '.MAT'.

Step-2: Now, the generated '.MAT' signal is then loaded into the toolbox by selecting the load signal option from the file menu.

Step-3: The signal is then analyzed for the required level of decomposition by choosing the daubechies wavelet '4' from the wavelet family menu.

After performing these steps, the decomposition of the signal can be obtained along with the corresponding wavelet coefficients to identify and classify different power quality disturbances.

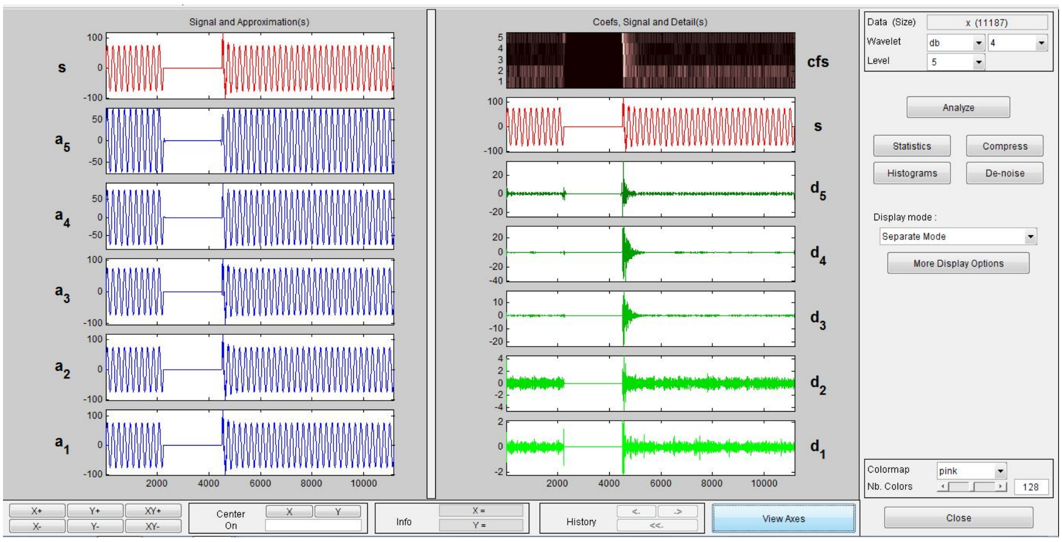

Fig. 2 Decomposition of momentary interrupted signal

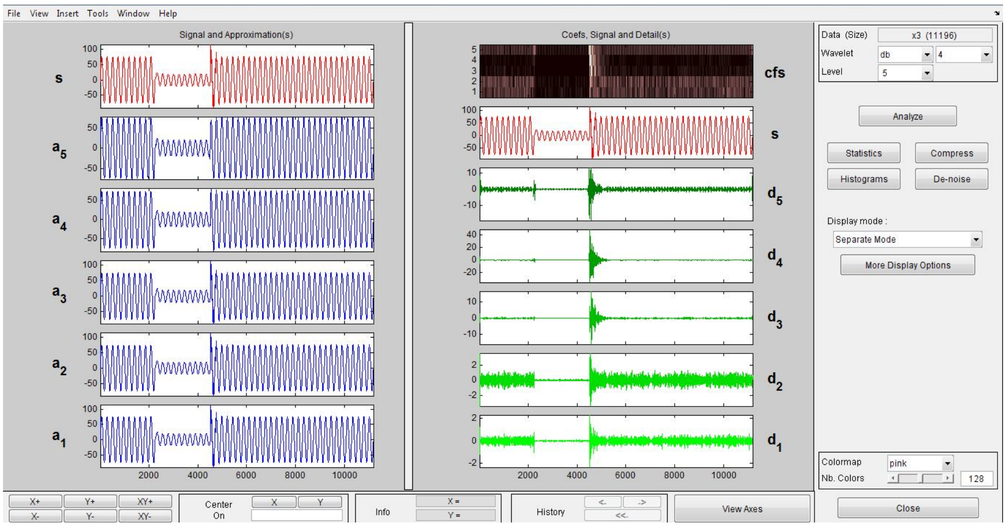

Fig. 3 Decomposition of voltage sag

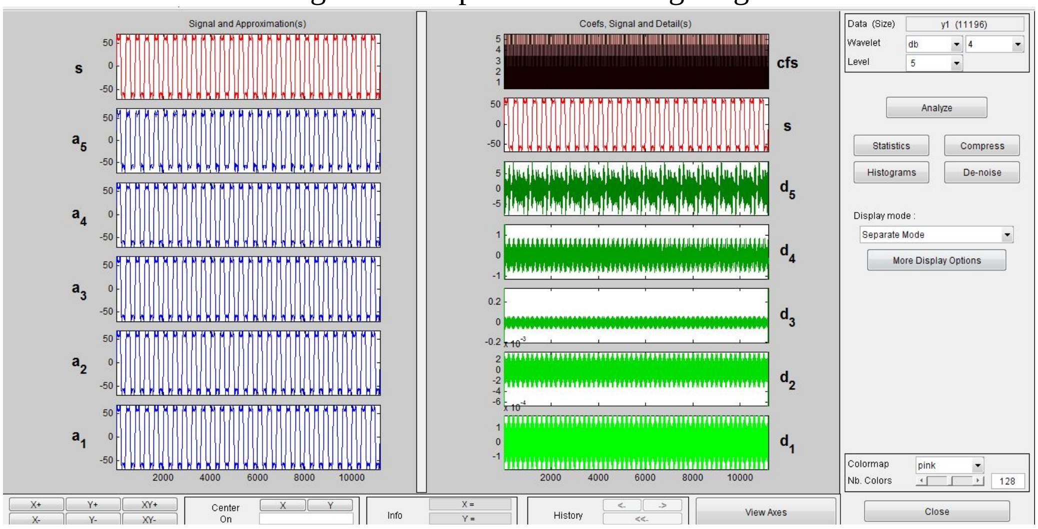

Fig. 4 Decomposition of voltage signal with harmonics

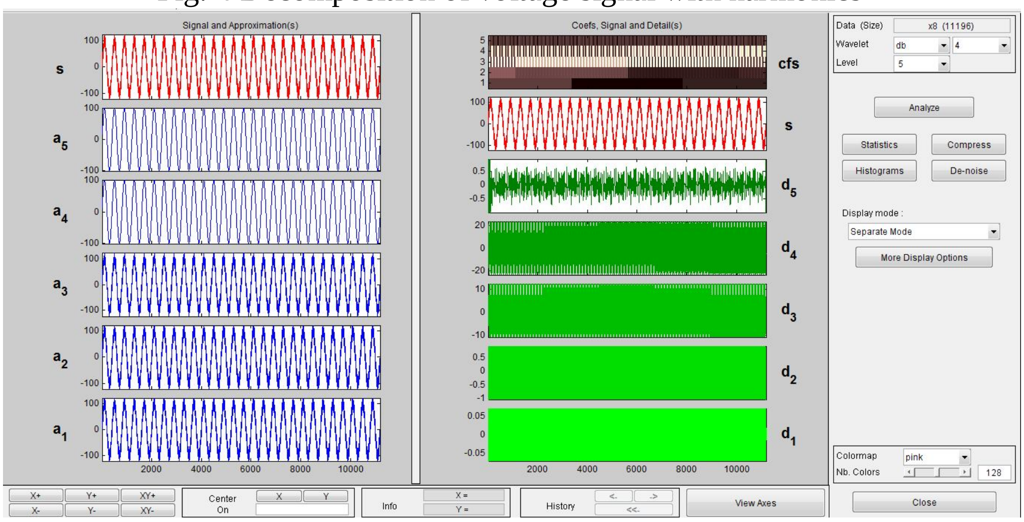

Fig. 5 Decomposition of voltage signal with noise

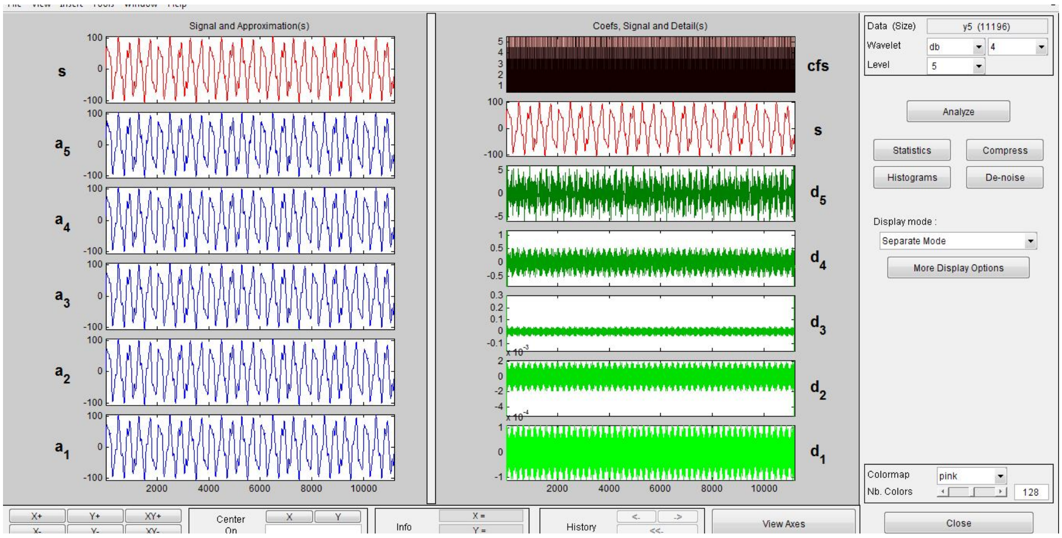

Fig.6 Decomposition of voltage signal with sub-harmonic

CONCLUSION

The above figures shows decomposition of different power quality disturbances using db4 wavelet at level five. The rms values of approximate and detailed coefficients for a 300V signal are calculated and tabulated.

Rms	A5	D5	D4	D3	D2	D1
Swell	322.380	8.445	9.1313	2.1431	0.8731	0.2887
Sag	268.316	8.668	9.6782	2.4862	0.8397	0.2608
Interruption	265.566	10.80	10.055	3.0724	0.8682	0.2796
Noise	396.905	2.245	50.579	17.487	1.3823	0.0698
harmonics	315.4853	20.461	1.1771	0.5671	0.1205	0.0048
Pure Sine	297.7899	5.5395	1.4253	0.08086	0.9119	0.2899
Inter harmonics	315.7172	14.1636	1.2132	0.904	0.0965	0.0036
Sub harmonics	318.35	1.8913	0.4143	0.02556	0.0527	0.0020

From the above analysis it can be concluded that the approximate coefficient at level 5 for voltage sag and moment interruption is less than the pure sine wave. For harmonics and inter harmonics the rms values of approximate coefficients at level 5 are greater than pure sine wave and the rms values of detailed coefficients level 5 are greater than a pure sine wave. For noise signal the rms values of A5 D4, D3, D2 and D1 are greater than a pure sine wave. For harmonics, sub-harmonics and inter harmonics detailed coefficients at level 1 & 2 are less than pure sine wave.

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