Detection of Power Quality Disturbances Using Wavelet Transforms

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Abstract

A new method for detection of power quality disturbance is proposed: first, the original signals are de-noised by the wavelet transform; second, the beginning and ending time of the disturbance can be detected in time, third, determining the cause of power quality disturbances using various approaches such as Multi Resolution Analysis (MRA) or Discrete Wavelet Transforms (DWT). In this paper, wavelet transform is proposed to identify the power quality disturbance at its instance of occurrence. Power quality disturbances like sag, swell, interruption, DC offset, frequency variation and harmonics are considered and are decomposed up to 4 levels using Db4 wavelet. For some disturbances it is sufficient to have only second or third level of decomposition. The exact location of the disturbance can also be found on the time scale. The application to a case study shows that this method is fast, sensitive, and practical for detection and identification of power quality disturbance.

Keywords: Daubechies (Db), Discrete Wavelet Transform (DWT), Multi Resolution Analysis (MRA), Power Quality (PQ).

1. INTRODUCTION

Electric Power Quality (PQ) is a very important issue as far the power supply utilization is concerned. It is the measure of electric power supply quality reached to the customer end for their specific utilization. Voltage levels, Harmonics, Flickering, distortion of wave are the key parameters which decide the power quality. If these parameters are not healthy, then it is considered as poor quality of power supply. In order to improve electric power quality, the sources and causes of disturbances must be known before appropriate mitigating action can be taken and continuous recording of disturbance waveforms is necessary. Unfortunately, most of these recorders rely on visual inspection of data record creating an unprecedented volume of data to be inspected by engineers.[1] Wavelet Transform (WT) is a mathematical tool, which provides an automatic detection of Power Quality Disturbance (PQD) waveforms, especially using Daubechies family. Several types of Wavelets Network algorithms have been considered for detection of power quality problems. But both time and frequency information’s are available by Multi Resolution Analysis(MRA) alone[1].

A power quality problem can best be described as any variations in the electrical power service, such as voltage dips, fluctuations, momentary interruptions, harmonics and transients, resulting in maloperation or failure of end-user
equipment. Wavelet Transform provides the time-scale analysis of the non-stationary signal\[1\][2]. It decomposes the signal to time scale representation rather than time-frequency representation. Wavelet transform (WT) expands a signal into several scales belonging to different frequency regions by using translation (shift in time) and dilation (compression in time) of a fixed wavelet function known as Mother Wavelet. Wavelet based signal processing technique is one of the new tools for power system transient analysis and power quality disturbance classification and also transmission line protection. The Discrete Wavelet Transform and Multi Resolution Analysis (MRA) provides a short window for high frequency components and long window for low frequency components and hence provides an excellent time frequency resolution. This allows wavelet transform for analysis of signals with localized transient components.

In this paper, other transformation techniques like Fast Fourier Transforms and their comparison with Wavelets was done in terms of Exactness in retrieving the information was done. And a brief review about the DWT and MRA was dealt. With the help of MATLAB/ Simulink in a transmission line the disturbances were introduced for analysis. With the help of Daubechies as mother Wavelet decomposition was done using MATLAB-Wavelet Toolbox up to fourth level, according to the accuracy of information obtained. Finally the detection of all the six types of disturbances was done.

**A. Wavelet Transforms**

Fourier Transforms gives information about the frequency contents of the signal. But it doesn’t give information about the time of occurrence of the frequency. Hence suitable for stationary signal analysis where frequency component doesn’t vary with time.

A wavelet is a transient signal that can be defined as an oscillatory function, or a non-stationary signal which has a zero mean, and decays quickly to zero. The wavelets are functions that satisfy certain mathematical requirements and are used in representing data or other functions. The fundamental idea behind wavelets is to analyze according to scale\[3\].

The wavelet transform procedure is to adopt a wavelet prototype function, called an analyzing wavelet or mother wavelet. Frequency analysis is performed with contracted, high frequency version of the prototype wavelet and a dilated, low frequency version of the prototype wavelet.

Other applied fields that are making use of wavelets are astronomy, acoustics, nuclear engineering, sub band coding, signal and image processing, neurophysiology, music, magnetic resonance imaging, speech discriminations, optics, earthquake predictions, radar, human vision, and in pure mathematics applications such as solving partial differential equations.
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The wavelet transform, as frequencies increase, the time resolution increases; like wise, as frequency decrease, the frequency resolution increases. Thus a certain high frequency component can be located more accurately in time then a low frequency component can be located more accurately in the time a low frequency component and a low frequency component can be located more accurately in frequency compared to high frequency component.

The extensive use of the wavelet transform in various fields is due to its variety of properties

2. Discrete Wavelet Transform (DWT) & Multi-Resolution Analysis (MRA):

Wavelets have been applied successfully in a wide variety of research areas such as signal analysis, image processing, data compression, de-noising and numerical solution of differential equations [5]. In recent years, wavelet analysis techniques have been proposed extensively in the literature as a new tool for fault detection, localization and classification of different power system transients.

In this paper we present the wavelet-multi-resolution analysis as a new tool for extracting the distortion features. The MRA is a tool that utilizes the DWT to represent the time domain signal $f(t)$ can be mapped into the wavelet domain and represented at different resolution levels in terms of the following expansion coefficients:

$$C_{\text{signal}} = [C_0|d_0| d_1|---d_{f,n}|] \quad \ldots \ldots (1)$$

Where, $d_i$ represent the detail coefficients at different resolution levels, and $C_0$, presents the last approximate coefficients. Wavelet transform can be achieved by convolution and decimation. The detail coefficients $d_j$, and the approximated coefficients $c_j$ can be used to reconstruct a detailed version $D_2$ and an approximated version $A_1$, of signal $f(t)$ at that scale. Effectively the wavelet coefficients $h(n)$ and the scaling function coefficients $h_0(n)$ will act as high pass and low pass digital filters respectively. The frequency responses $H_0(\omega)$ and $H_1(\omega)$ of the mother wavelet Daubechies (Db4) and its scaling function are shown in Fig.2. These two functions divide the spectrum of the input signal $f(t)$ equally [5-6].
Decimation (or down sampling) is an efficient multi-rate digital processing technique for changing the sampling frequency of a signal in the digital domain and efficiently compressing the data. As indicated in Fig. 2, the sampling rate compression and data reduction in detail coefficients are achieved by discarding every second sample resulting from convolution process. Since half of the data is discarded (decimation by 2), there is a possibility of losing information (aliasing); however the wavelet and the scaling function coefficients \( (h_1(n) \) and \( h_0(n) ) \) will act as digital filters that limit the band of the input \( c_{j+1} \) and prevent aliasing.

**A. Daubechies Family Wavelets**

As per IEEE standards, Daubechies wavelet transform is very accurate for analyzing Power Quality Disturbances among all the wavelet families, for transient faults. The names of the Daubechies family wavelets are written as DbN, where N is the order, and db the “surname” of the wavelet. (Fig.)

**Power Quality Disturbances That Are Analyzed Using DWT-MRA are listed as follows[7-9]:**

1. Voltage sag / under voltage / sustained Under Voltage
2. Voltage swell/ over voltage / sustained Over Voltage
3. D.C. Offset
4. Power frequency variation
5. Interruption
6. Hormonics of order seven
C. Results

The disturbance signals generated using the simulation diagram are as follows:

![Disturbance signals](image1)

- (a) Sag with 30% load
- (b) Swell with 30% load
- (c) D.C Offset
- (d) Frequency variation
- (e) Interruption
- (f) Harmonics of order 7

The decomposed signals are shown as follows in the next set of figures:

![Decomposed signals](image2)

- (a) Sag with 30% load
- (b) Swell with 30% load
- (c) Harmonics of order 7

Fig 7. (a), (b), (c), (d), (e), (f) Wavelet decomposition of Power Quality Disturbances using Db4 & level4.

4. CONCLUSIONS

Power system events may be classified by quantity and duration of power quality disturbances in Fig 7(a), (b), (c), (d), (e), (f). This paper has presented a method to detect the disturbed voltage waveforms of arbitrary sampling rate and number of cycles. Even the visual observations can state the occurrence and the duration of disturbance very easily.

Hence we can conclude that the wavelet MRA can effectively detect any type of PQD at a faster rate.
ACKNOWLEDGMENT

The authors would like to thank the officials of JNTU College of Engg., Hyderabad for providing the facilities to carry out this work.

REFERENCES


