International Journal of Electrical, Electronics and Computer Engineering **2**(2): 47-53(2013)

ISSN No. (Online): 2277-2626

Investigations on Power Quality Disturbances Using Discrete Wavelet Transform

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(Received 07 June, 2013, Accepted 05Augest, 2013)

ABSTRACT: Extensive use of power electronic devices and non-linear loads in electrical power system cause problem of power quality (PQ). Renewable energy sources are also integrated to the grid through power electronics based equipment. So the power quality issues are drawing attention in recent years. PQ disturbance need to be detected accurately It is also essential to find out the cause of such an event. Detection and classification of PQ disturbance helps to control such event. In this paper, wavelet transform is applied to notice, localize, and extract power signal disturbance. To study various power quality disturbances, a model simulated using MATLAB/Simulink toolbox. The key plan underlying in the approach is to decompose a given disturbance signal into alternative signals that represent a smoothened version and a close version of the first signal. Using multi resolution analysis signal is decomposed.

Keywords: Discrete Wavelet Transform (DWT), Momentary interruptions, Multiple resolution analysis (MRA), Voltage sag, Voltage swell, Wavelet Transform (WT).

I. INTRODUCTION

The quality of power supply has become a major issue for electrical utilities and electricity consumers. The poor quality of the power supply may cause malfunctions of power service equipments, instabilities, short life time of equipments, and so on. The power signal disturbances are classified as impulse, notches, glitches, momentary interruption, voltage sag, voltage swell, harmonic distortion and flicker. To improve the quality of the power supply, it is required to detect source of the disturbances accurately. The power quality events should be detected, localized and classified accurately so that proper mitigation measures could be applied [1, 2].

Wavelet analysis techniques have been implemented as a new tool for fault detection, localization and classification of different power system transients [4, 7, 9, 10, 11]. According to the literature, different wavelets can be used to decompose the signal. Commonly Daubechies (Db), biorthogonal (bior) and coiflet has used for identifying the imbalance in active power in power system. Wavelet families can be found in detail in the reference [13], throwing light on properties of wavelets.

Wavelets are mathematical functions that divide data into different frequency components. These frequency components are simple and easy to study. The basic idea in wavelets is to analyze signal according to scale rather than frequency. Wavelet has been used for the analysis of signal with discontinuities and sharp spikes. By using wavelet multi resolution analysis, a proof is pictured by a finite add of elements at totally different resolutions in order that every element is adaptively processed supported the objective of the application [3-5].

This paper is divided in eight different sections. Definition and discussion on power quality disturbances are the main focus of section II. Analytical methods used commonly by different researcher to detect signal disturbance are described in section III. Highlight on application areas of wavelet presents in section IV. In this model, various disturbances like voltage sag, swell, harmonics and interruption are simulated in section V. Wavelet toolbox is used to obtain discrete wavelet transform on imported signal, obtained through model results. Section VII and VIII are emphasizing on results and conclusion respectively.

II. POWER QUALITY DISTURBANCES

Detection of power quality disturbances has become a major issue. According to International Electro technical Commission (IEC) impulsive and oscillatory transients, brief interruption, harmonic distortion, voltage swell or sag are considered as disturbances.

The power quality disturbance is a temporary deviation in value from the steady state value due to sudden change of load and faults. Definition and causes of different disturbance are describe below according to IEEE Std-1159, 1250.

A. Voltage Sag

Voltage sag is a short-duration decrease of the Root Mean Square (RMS) voltage (between 10% to 90%) that lasts from 0.5 seconds to several seconds. If it lasts for less than half a cycle then it is considered as transient. Voltage sag results due to switching operations of large motors, lightning strokes and transmission faults (disconnection of supply). These momentary events can cause a complete shutdown of power plants, which may take hours to return to normal operation [2].

B. Voltage Swell

An increase in RMS value of voltage from 1.1p.u. to 1.8p.u., and the lasting time is 0.5 period to 1min. is known as voltage swell. A voltage swell occur temporary, on the phase without fault of a three phase circuit due to single line to ground fault. They can also occur on adding a large capacitor bank, removing a large load and due to transfer of loads from one power source to another.

C. Harmonics

A harmonic is a sinusoidal component of a periodic wave or signal having a frequency that is an integer multiple of fundamental frequency. The term harmonic refers to the decomposition of a non-sinusoidal but periodic signal into a sum of sinusoidal components.

$$f(t) = \sum_{n=1}^{\infty} A_n \cos(2\pi h f_0 + \emptyset_n) \quad (1)$$

Where A_n and ϕ_n are amplitude and phase angle for harmonic order.

Either time-domain or frequency domain approach can be used for harmonic analysis. Harmonics are mainly caused by non-linear loads. Harmonic distortion has become progressively more important in recent years, due to the increase in nonlinear loads.

D. Voltage Interruption

Temporary interruptions may be thought of as voltage sags with 100% amplitude or large percentage loss of voltage. Interruptions are caused by a transient fault. During short interruption, voltage level is to be close to zero. The causes may be a blown fuse, or breaker gap that leads right down to the ending of the facility system set inflicting large loss.

E. Transients

Voltage disturbances which persist shorter than sags or swells are classified as transients. These are caused by the sudden changes in the power system. The transient over voltage of duration in the range of milliseconds are called switching surge and in the range of microseconds are called impulse spike.

III. ANALYSIS METHODS

A. Fourier Transform (FT)

The Fourier transform gives information about the presence of different frequency components of the signal. It gives information of different frequency component exists in the signal, but FT do not provide information, when in time these frequency components exist. For stationary signal whose frequency component does not change in time, this information is not required. Time frequency representation of signal is required for non stationary signals. Short Time Fourier Transform (STFT) is better than FT but it gives fixed resolution all the times due to fixed window size.

B. Wavelet Transform (WT)

In wavelet analysis, the use of a totally scalable modulated window resolves the difficulty of signal-cutting [5]. It gives variable resolution. Translation and scaling is used to generate wavelets from a single basic wavelet. This single basic wavelet is called as mother wavelet. In wavelet analysis, we get details and approximations. The details are the low scale, high-frequency components and the approximations are the high-scale, low-frequency components of the signal. The strength of the wavelet analysis is its ability of representing signals in compact from and in many levels of resolutions. There are two types of wavelet transforms; discrete wavelet transforming (DWT) and continuous wavelet transform (CWT). The prime difference between discrete wavelet transform and continuous wavelet transform is that discrete wavelet transform use a explicit subset of scale and translation values and continuous wavelet transform uses all possible scale and translation. In reference [9] author uses the continuous wavelet transforms to find out time duration of the disturbance and the DWT to calculate the disturbance amplitude.

C. Discrete wavelet transforms (DWT)

The signal is passed through a series of low pass and high pass filter to generate discrete wavelet transform. In filtering process the original signal is passed through two complementary filter and we get two decomposed sequences A and D. This process produces DWT coefficients.

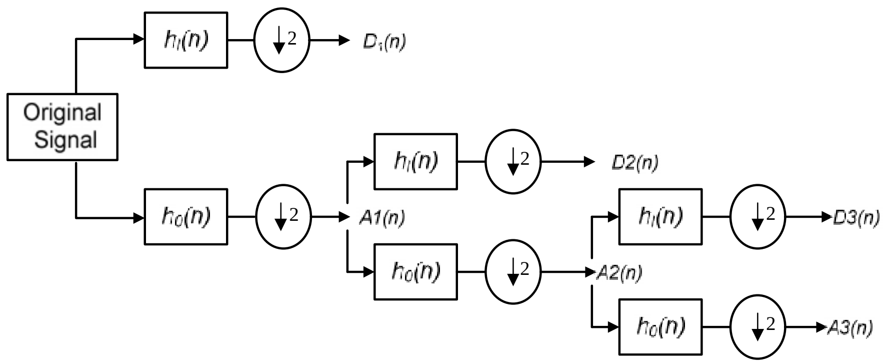

Fig. 2. Signal three level decomposition Using MRA.

To extend the frequency resolution, decomposition of signal is done repeatedly and signal can be realized into two lower frequency ranges. This process is known as multi resolution analysis. Approximate coefficients A1(n) and detail coefficients D1(n) obtained after passing the signal through low pass and high pass filters, at level 1. Approximation coefficients A1(n) are down sampled further with high and low pass filters as shown in Fig. 2. The approximate coefficients A2(n) are then filtered again to obtain the next level of coefficients. This filtering operation progresses in this way.

$$y[n] = (x \times g)[n] = \sum_{k=-\infty}^{\infty} x[k]g[n-k] \quad (2)$$

$$y_{low}[n] = \sum_{k=-\infty}^{\infty} x[k]g[2n-k] \quad (3)$$

$$y_{high}[n] = \sum_{k=-\infty}^{\infty} x[k]h[2n-k] \quad (4)$$

Notation used in (2), (3) and (4) are y - original signal, g – high pass filter, h – low pass filter. This decomposition has halved the time resolution since only half of each filter output characterizes the signal. However, each output has half the frequency band of the input so the frequency resolution has been doubled.

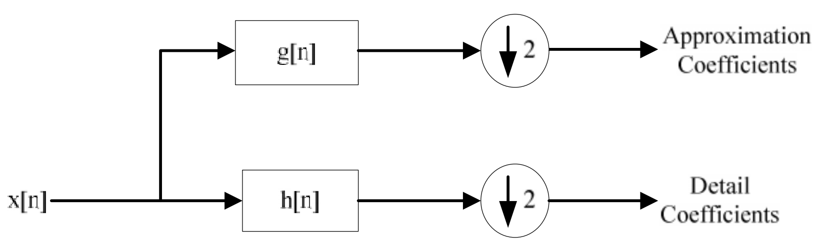

Fig. 3. Block diagram of filter analysis.

At each level in Fig. 3, the signal is decomposed into low and high frequencies. Due to the decomposition process the input signal must be a multiple of 2^n where n is the number of levels.

IV. WAVELET APPLICATION

In major areas of research such as signal and image processing, speech discriminations, data compression, de-noising and numerical solution of differential equations, medical diagnostics and many others wavelets have been applied successfully [7]. In reference [12], use of discrete wavelet transform for evaluation of the low frequency electromechanical oscillations in power systems and found more accuracy in results during active power imbalance in a power system.

V. A SIMULINK MODEL CREATED TO STUDY VOLTAGE SAG, VOLTAGE SWELL AND HARMONICS

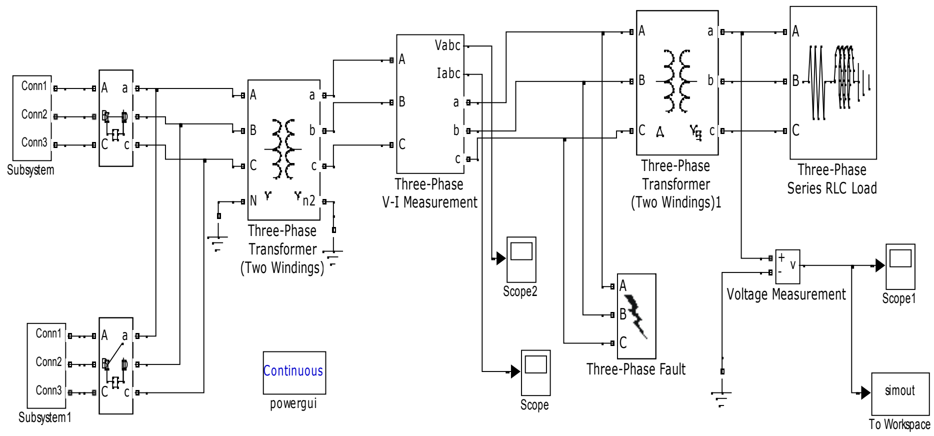

Fig. 4. A simulink model.

The disturbances like voltage sag, swell, harmonic and interruption are generated in simulink model shown in Fig. 4. Discrete wavelet transform can detect these disturbances and provides information in both time and frequency domain. Selection of mother wavelet plays an important role in finding out and localizing the power quality disturbances. As discussed in [10], for short and fast transient disturbances, Daub4 and Daub6 wavelets are good choice, while for slow transient disturbances, Daub8 and Daub10 are better. Discrete wavelet transform is applied and four-level decomposition is done using daubchies4.

VI. WAVELET RESULTS

According to IEEE standards, Daubechies wavelet is very precise tool to monitor power quality disturbances among all the wavelet families. Signal obtained after using discrete wavelet transform, distinct rippling rework for voltage sag, voltage swell and harmonic area unit displayed in Fig. 5, Fig. 6, Fig. 7 and Fig. 8.

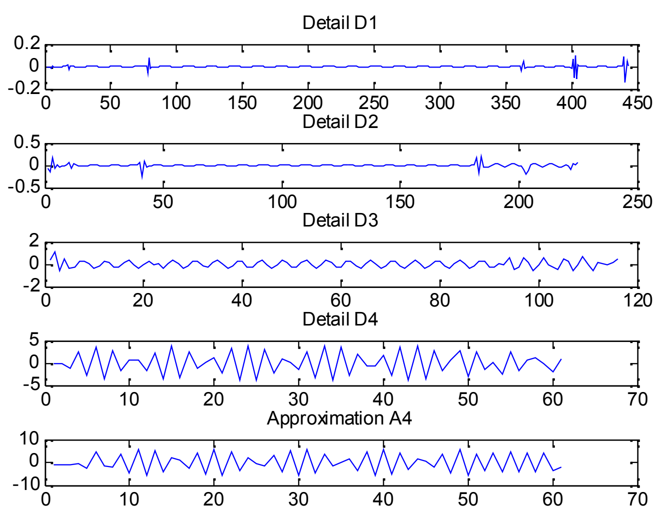

Fig. 5. DWT of voltage sag.

The approximation reveals the regular pattern of the signal. Details d1 is enough to produce precise time data for any type of disturbance. Higher levels of decomposition area unit largely accustomed extract additional data needed for classification. From all the 3 Figure, one can simply observe starting and ending time of any disturbance, the WTCs has terribly high value.

Fig. 5 displaying the approximation and detailed version of voltage sag. From the Figure, sag can be easily detected at the lower scale. The starting time of sag is at 4 ms and lasts till 4.5 ms and therefore the duration of sag event can be detected and localized in lower levels. The detailed version of voltage swell in Fig. .6 obtained through finer resolution level. The voltage swell occurs at 8 ms can be easily detected as these disturbances perpetually found to possess a pattern in initial level info.

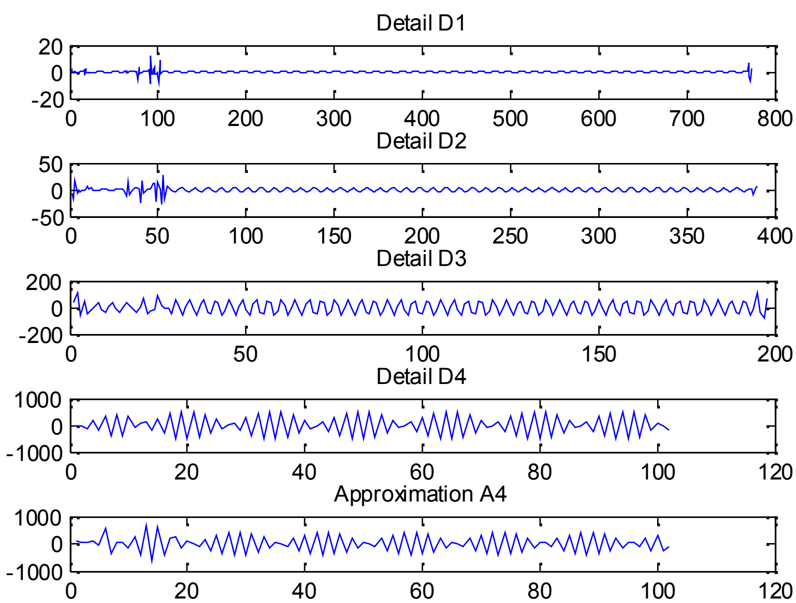

Fig. 6. DWT of voltage swell.

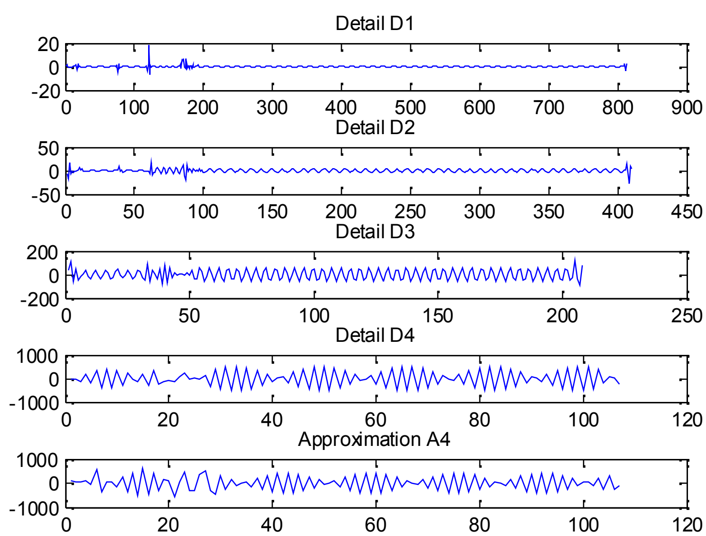

Fig. 7. DWT of voltage harmonics.

The MRA decomposition of voltage harmonics are shown in Fig. 7. The detection results at scale 1, showing disturbance occurred at 1.34 ms and end at 1.67ms. These disturbances always found to have a pattern in first level. Fig. 8 show the detailed version of four-level decomposition .Voltage interruption is detected and localized at first two finer resolution levels. This is because at the lower scales, the analyzing wavelet is more localized. The starting time of the interruption is 0.35 ms and the ending time 0.45 ms can be observed easily . The duration of voltage interruption can be found out by difference of starting time and ending time.

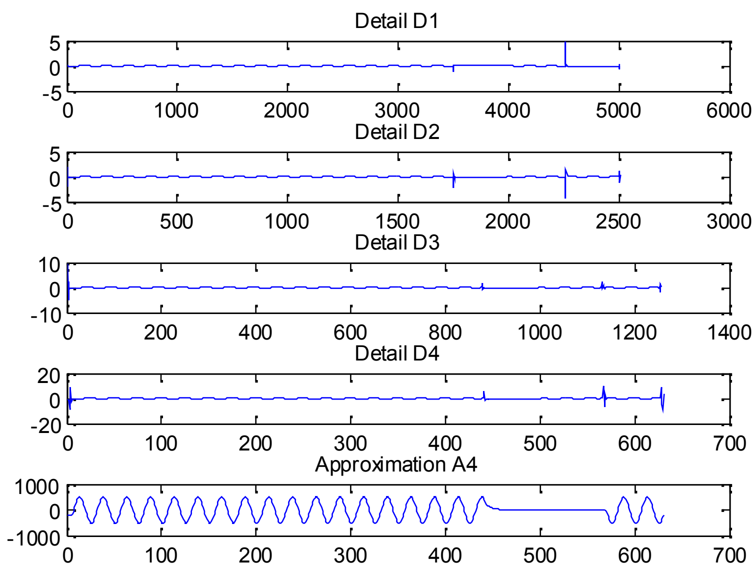

Fig. 8. DWT of voltage Interruption.

VII. CONCLUSION

The sources of power quality disturbances must be known for improving the power quality. The proposed technique found better for detection and localization of power quality disturbances. This technique accurately locates voltage sag, swell, harmonic distortion and interruption. The results show correct classification of events will he performed by human experts. Unlike Short Term Fourier Transform, the analysis isn't depends on window size. This methodology will he extended to observe other PQ events that require to be monitored. This could be utilized for achieving on-line, low cost PQ monitoring real time system. Further Artificial Neural Network, Neuro fuzzy system, hybrid intelligent systems, space vector machine etc can be use for classification of disturbances by processing the results obtained through wavelet transform.

REFERENCES

[1]. Lin, C.-H. Tsao, M.-C. "Power quality detection with classification enhancible wavelet-probabilistic network in a power system" Generation, Transmission and Distribution, *IEEE Proceedings*- 4 Nov. 2005 Volume: **152** ,Issue: 6 On pages : 969 - 976

[2]. Dugan R.C., McGranaghan M.F., Santoso S. & Beaty H.W., "Electrical Power Systems Quality", McGraw Hill, ISBN 0-07-138622-X, USA, 2003.

[3]. Wavelet Toolbox User's guide by The Math works.

[4]. Santoso S., Powers E. J., Grady W. M. and Hoffmann P., "Power quality assessment via wavelet transform analysis," *IEEE Transactions on Power Delivery*, Vol. **11**, pp. 924–930, Apr. 1996.

[5]. A Really Friendly Guide to Wavelets – © C. Valens, 1999 c.valens@mindless.com

[6]. Robi Polikar, 'The Wavelet Tutorial', 136 Rowan Hall, Department of Electrical and Computer Engineering, Rowan University, Glassboro, NJ 08028, June 1996.

[7]. M. Misiti, Y. Misiti, G. Oppenheim and J.-M Poggi (2006), *Wavelet Toolbox For Use With Matlab: user's guide version 3*, Mathworks Inc.

[8]. M.H.J. Bollen 2000, "Understanding Power Quality Problems", Piscataway, NJ: IEEE Press.

[9]. L. Angrisani, P. Daponte, M.D' Apuzzo and A. Testa," A Measurement Method Based on the Wavelet Transform for Power Quality Analysis", *IEEE Trans. Power Delivery*, Vol. **13**, pp.990-998, Oct. 1998.

[10]. S. Santoso, E.J. Powers, and W.M. Grady, "Electric power quality disturbance detection using wavelet transform analysis," in Proceedings of the IEEE-SP International Symposzum on Tzme-Prequency and Time-Scale Analysis, Philadelphia, PA, Oct. 25-28, 1994, pp. 166-169.

[11]. D. Saxena, S.N. Singh and K.S. Verma, "Wavelet based denoising of power quality events for characterization", *International Journal of Engineering, Science and Technology*, Vol. **3**, No. 3, 2011, pp. 119-132.

[12]. Samir Avdakovic, Amir Nuhanovic, Mirza Kusljugic, Mustafa Music, Wavelet transform applications in power system dynamics", *Electric Power Systems Research*, **83** (2012) 237– 245.

[13]. Daubechies, "Ten Lectures on Wavelets", Society for Industrial and Applied Mathematics, Philadelphia, PA, 1992.