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Detection and Recognition of Power Quality Disturbances using Stationary Wavelet Transform

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ABSTRACT

This paper presents the method for detecting power quality disturbances using Stationary Wavelet Transform (SWT). The disturbance time information and level will be known from the frequency sub-bands of original signal. Lifting Wavelet Transform which eliminates the aliasing problem presents in conventional method such as Discrete Wavelet Transform (DWT) and that makes good reconstruction from the sub-bands of original signal. The absence of time invariance property in LWT can be eliminated by upsampling the filter coefficients in SWT. The output obtained from the Stationary Wavelet Transform, Lifting Wavelet Transform and conventional method of Discrete Wavelet Transform will be compared for various disturbances and Simulation results are given.

Keywords: Harmonic disturbances, Power quality, Lifting scheme and noise.

1. INTRODUCTION

Nowadays, importance of power quality plays a major role in Power system networks. The power quality disturbance can be caused deviation in power system, such as harmonics, oscillations, quick disruptions, transients and it leads to faulty operation or letdown of concern equipment. The harmonic presents in power system distorts the power system signal which in turn creates various complications. Conventionally, for harmonic analysis, the discrete Fourier transform (DFT) is suggested which provides frequency information of the signal, but it will not give time information required [1]. Thus, DFT is only adoptable to stationary signals.

Power quality can be improved by introducing proposed technique for various disturbances to overcome the disadvantages in the conventional methods. Wavelets are a set of functions which can be used to display the transient phenomena from the sub-bands of original signal. To analyze non–stationary signals, the Wavelet Technique is an efficient signal processing tool and also it has wide variety of applications [5].

In power quality analysis using wavelet technique, the signal will be compared to wavelet function, and the coefficients which are obtained gives information of relationship of wavelet function with the original signal. At high frequencies, the Wavelet Transform (WT) provides decent time resolution but the frequency resolution is not good. Similarly at low frequencies, it gives decent frequency resolution but the time resolution is not good. It is useful specifically whenever the signal has high frequency quantities for small intervals and low frequency quantities for long intervals.

In order to eliminate the resolution difficulties obtained in Wavelet Transform, a different methodology called wavelet packet transform (WPT) is introduced to analyze any signal [8]. In WPT, the approximations and details can be divided and analyzes the input at various frequencies with various resolutions [2]. But in some cases, the information obtained from wavelet features is not enough for the certain ranges.

In this paper, new algorithms are presented and applied to identify disturbance time and energy analysis from approximation/detail coefficients. Lifting Wavelet Transform which eliminates the aliasing problem presents in conventional method such as Discrete Wavelet Transform (DWT) and that ensures perfect reconstruction. The absence of time information in LWT can be eliminated by upsampling after the filter operation in SWT. Finally, the output obtained from different methods such as Wavelet Packet Transform (WPT), Lifting Wavelet Transform (LWT) and Stationary Wavelet Transform (SWT) will be analyzed and compared for various conditions.

2. PARSEVAL'S THEOREM

Parseval's theorem commonly states that the summation (or integration) of the function square is equal to the summation (or integration) of the transform square [3]. The succeeding equation that is Parseval's theorem helps to determine various level of energy from the details.

$$\frac{1}{N}\sum_{k=1}^{N}|f(k)|^2 = \frac{1}{N}\sum_{k=1}^{N}|a_J(k)|^2 + \sum_{J=1}^{J}\left(\frac{1}{N}\sum_{k=1}^{N}|d_J(k)|^2\right) \quad (1)$$

The approximations and details obtained from the original signal are denoted in the above equation (1) and those coefficients are used for analysis purpose and detection of power quality issues. The level of division depends on the disturbance occur in power system network. The method can be denoted mathematically by:

$$P_J = \frac{1}{N}\sum_{k=1}^{N}|d_J[k]|^2 = \frac{\|d_J\|^2}{N} \quad (2)$$

Where, $\|d_J\|$ is the norm of the extension coefficient d_J,

$$P_J = (P_J)^{\frac{1}{2}} \quad (3)$$

3. LIFTING WAVELET TRANSFORM

The LWT is an improved methodology while compared to conventional method of wavelet transform. It compute the predict process and stores the details required which is called

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lifting. It comprises of two interchanging lifting steps. In the first step, the low pass coefficient is stable and high pass coefficient is variable. In the second step, the high pass coefficient is stable and low pass coefficient is variable. There are three steps in LWT which are (i).split, (ii).predict and (iii).update which is displayed in Fig. 1.

After completion of splitting, the information required will be analyzed from the coefficients. Then the process of reconstruction will begin and it is simple in lifting wavelet transform [4]. The reconstruction process is the reverse operation of decomposition to obtain the original signal.

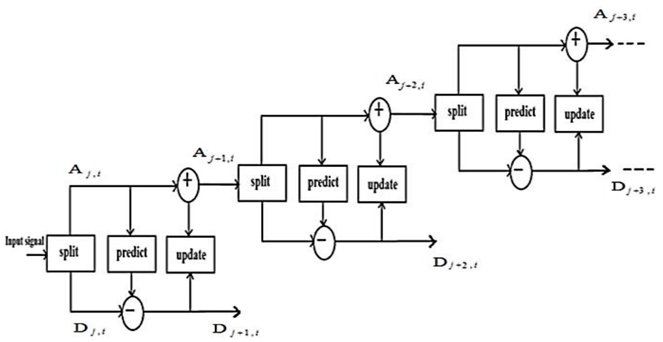

Fig. 1 Lifting Scheme

(1). Split

It will split the given original signal S_i into two coefficients, the approximations $A_{j,i}$ and details $D_{j,i}$. The odd and even samples are divided in the split step from the original signal.

$$F(s)=(A_{j,i},D_{j,i}) \quad (4)$$

(2). Predict

After completion of split, based on approximation and the real data, the predict step adjusts the samples without disturbing the even samples. Here the odd samples are predicted from even sample and it is given by the equation:

$$D_{j+1,i}=D_{j,i}-P(A_{j,i}) \quad (5)$$

$$P(A_{j,i})=\frac{(A_{j,i}+A_{j,i+1})}{2} \quad (6)$$

(3). Update

In the update step, the signal obtained from the predict step will be changed by replacing the even sample based on average value. The odd sample presents in the signal signify the original signal approximation.

$$A_{j+1,i}=A_{j,i}+U(D_{j+1,i}) \quad (7)$$

$$U(D_{j+1,i})=\frac{1}{4}\left(D_{j+1,i-1}+D_{j+1,i}\right) \quad (8)$$

4. STATIONARY WAVELET TRANSFORM

The SWT is the method which overcomes the drawbacks faced in the conventionally suggested methods. It gives the accurate time information and Redundancy will be achieved by upsampling the filtering sub-bands of original signal. The stationary wavelet transform is displayed in Fig. 2.

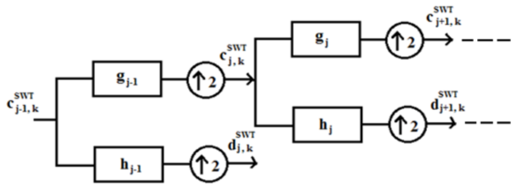

Fig. 2 Stationary Wavelet Transform

In DWT, the presence of downsampling will reduces the size of the coefficients. Due to reduced size, the process speed will get increased and it requires less storage. But it leads to the loss of required information for the analysis of the disturbances in the signal [6]. The SWT will be an alternative method for the identification of the power quality disturbances and locates the exact time of disturbance occur in power system in less computation time.

4. SIMULATION RESULTS

The algorithm proposed in this paper uses wavelet function of Daubechies 4 for the identification of numerous power quality issues. The fundamental frequency of 50 Hz and the sampling frequency of 1.6 kHz are used. The MATLAB simulation is used for identification of various disturbances occurs in power system. In our proposed system, the disturbances of harmonics, interruptions, voltage sag, voltage swell and oscillatory transients are taken for analysis purpose. The output obtained from the proposed system will be compared to the conventional methods available at various conditions.

4.1 Voltage Sag

For industry and commercial users, the voltage sag problem plays a major role and it creates many disturbances which lead to reduction of power quality.

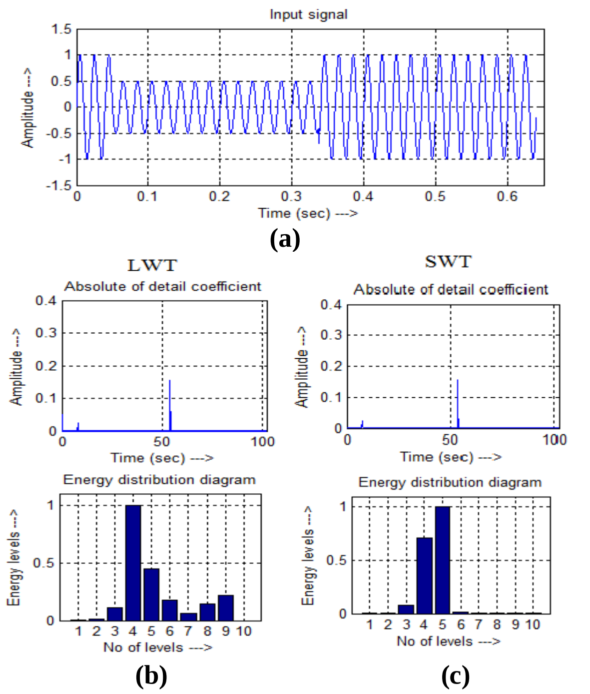

Fig. 3. (a) Sag signal (b) Output of LWT (c) Output of SWT

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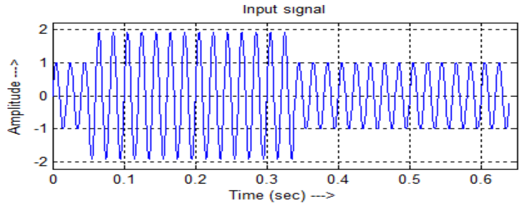
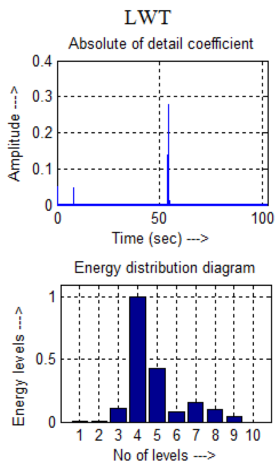
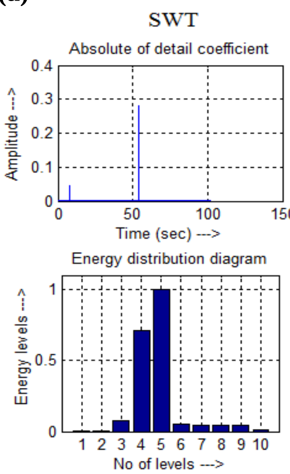
4.2 Voltage Swell

The amplitude of the signal raises upto 90% of the original that creates to many performance issues in power system. The considered voltage swell input and the concern results obtained from the proposed system are shown in Fig. 4. The time information of disturbance and time taken to compute the result with deviation level are displayed in Table I and Table II respectively and comparison graph is shown in Fig. 8.



(a)



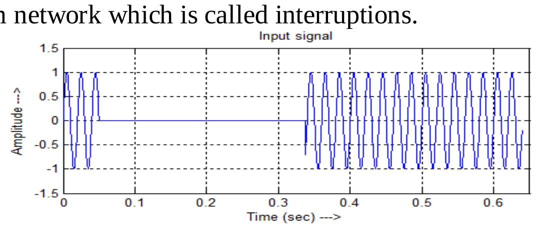


(b) **(c)**

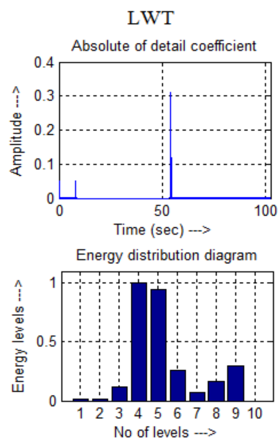
Fig. 4. (a) Swell signal (b) Output of LWT (c) Output of SWT

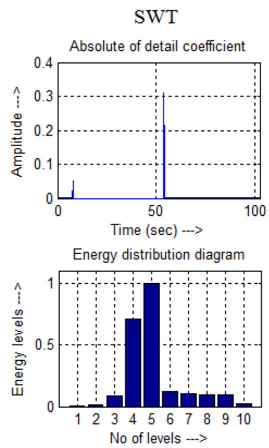
4.3 Interruptions

The voltage is suddenly drops to some percentage in power system network which is called interruptions.



(a)





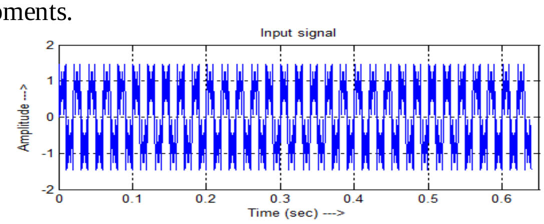
(b) **(c)**

Fig. 5. (a) Interruptions (b) Output of LWT (c) Output of SWT

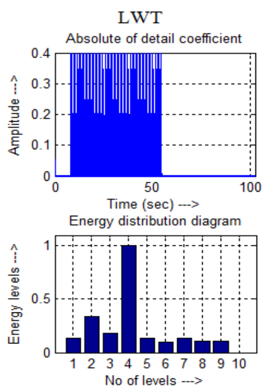
The considered disturbance input and the concern results obtained from the proposed system are displayed in Fig. 5. The time information of disturbance is obtained from the signal decomposition of input signal and it will be compared with conventional methods which are displayed in Fig. 9.

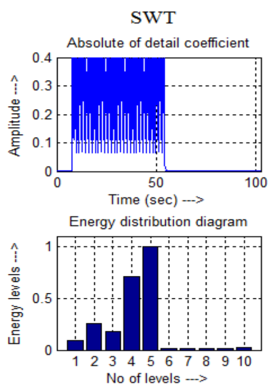
4.4 Harmonics

The harmonics occurs in power system lead to inefficient operation resulting in increases of losses in the entire system and also there will be some misoperation in devices and equipments.



(a)





(b) **(c)**

Fig. 6. (a) Harmonics (b) Output of LWT (c) Output of SWT

The considered harmonic input and the concern results obtained from the proposed system are shown in Fig. 6. The time information of disturbance and time taken to compute the result with deviation level is shown in Table I and it will be compared with conventional methods which are displayed in Fig. 8.

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4.5 Oscillatory Transients

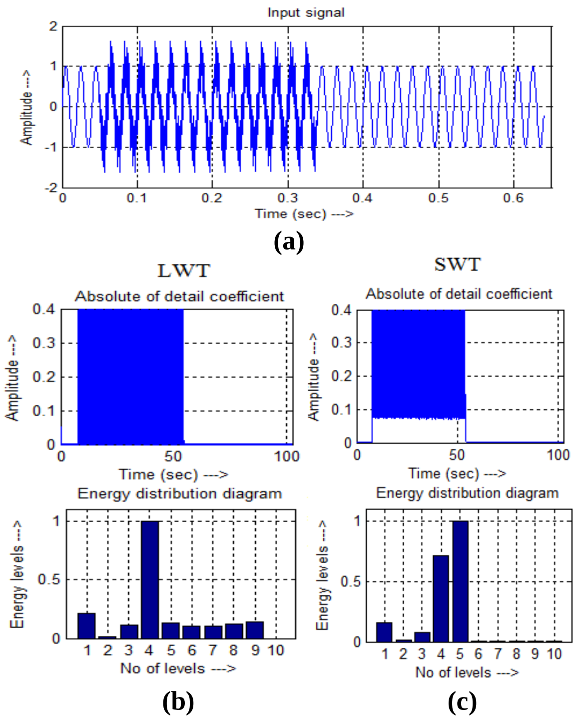

Fig. 7. (a) Oscillatory Transients (b) Output of LWT (c) Output of SWT

The oscillatory transients are the disturbances occur only for short duration when compared to voltage sag or swell. The considered disturbance input and the concern results obtained from the proposed system are shown in Fig. 7. The time information of disturbance and time taken to compute the result with deviation level are displayed in Table I and Table II respectively and it will be compared with conventional methods which are displayed in Fig. 8.

Table I
Computation time for different conditions using db4 Wavelet Function

Signal	Computation time (sec)		
	WPT	LWT	SWT
Sag	1.2804	0.6674	0.5927
Swell	1.2517	0.6751	0.5921
Interruptions	1.3259	0.6789	0.6095
Harmonics	1.3543	0.6675	0.5923
Oscillatory Transients	1.4732	0.6841	0.5916

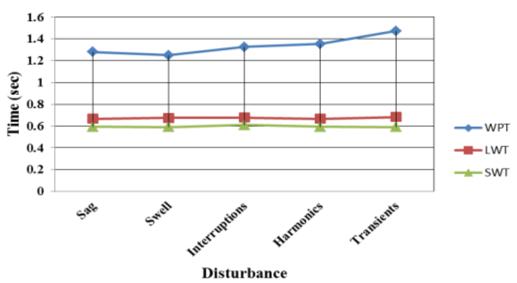

Fig. 8 Computation Time graph

From the Fig. 8, it is justified as SWT is an effective and time consuming tool for the analysis of disturbances in power system network. It provides the accurate information when compared to conventional methods and the errors calculated are compared which is displayed in Fig. 9.

Table II
Percentage Deviation for different conditions using db4 Wavelet Function

Signal	Theo. Dist. Time (sec)	LWT Actual Detected (sec)	SWT Actual Detected (sec)	WPT Deviation (%)	LWT Deviation (%)	SWT Deviation (%)
Sag	t1=8	t1=8.07	t1=7.95	0.69	0.49	0.33
	t2=54	t2=54.06	t2=53.98			
Swell	t1=8	t1=8.07	t1=7.95	0.73	0.49	0.32
	t2=54	t2=54.06	t2=53.99			
Interruptions	t1=8	t1=8.04	t1=7.98	0.47	0.28	0.11
	t2=54	t2=54.04	t2=54.01			
Harmonics	t1=8	t1=8.04	t1=7.98	0.32	0.18	0.11
	t2=54	t2=54.04	t2=53.97			
Transients	t1=8	t1=8.03	t1=8.02	0.41	0.24	0.14
	t2=54	t2=54.06	t2=54.04			

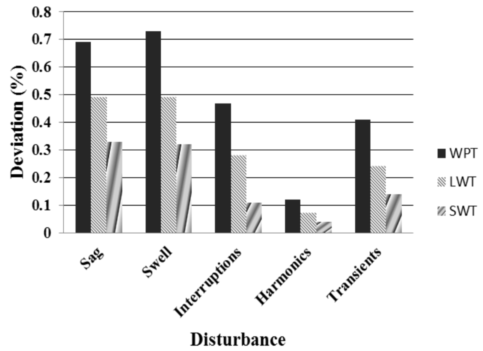

Fig. 9 Deviation comparison chart

5. CONCLUSION

The proposed paper suggests the stationary wavelet transform for the analysis of power quality issues occurs in power system. The results obtained from the various methods shows SWT is more precise in detecting disturbance time and consumes less time for computation. It is an alternating tool and efficient for the identification of power quality issues and the analysis gives the information required for mitigation of the disturbance occurs in power system.

REFERENCES

[1] EnrangZheng, Zhengyan Liu, Lingkum Ma, "Study on Harmonic Detection Method Based on FFT and Wavelet Transform", 2nd *International Conference ICSPS.*, vol. 3, July 2010.

[2] Shihong Wu, ZailinPiao , JianweiJI, Xiaoliang Li, Bo Hu, Ping Yang."Harmonics Detection in Electric Power Systems Based on Wavelet Packet Transform", *ICICTA.*, vol.2,May 2010.

[3] Cagri Kocaman, Muammer Ozdemir, "Comparison of statistical methods and wavelet energy coefficients for determining two common PQ disturbances: Sag and swell*", IEEE ICEEE*, Vol. 5, No. 2, Oct 2009.

[4] Min Li, Guang-pu He, Xiao-ying Zhang, Xiao-hong Wu, "Power Quality Detecting Based on Fast Lifting Wavelet

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

Transform*", IEEE conference on Power and Energy*, Vol. 19, No. 4, Oct 2008.

[5] Thangaraj.K, "Analysis of Harmonics using S-Transform", *International conference on Emerging Trends in Engineering, Technology and Science (ICETETS)*, 2016.

[6] Hao Ye, Guizeng Wang, and Steven X. Ding, "A New Parity Space Approach for Fault Detection based on Stationary Wavelet Transform*", IEEE Transactions on Automatic Control*, Vol. 49, No. 2, Oct 2004.

[7] ZHU Shou-xiand LiuHui, "Simulation study of power harmonic based on Daubechies Wavelet", *ICEEE International Conference.*, Nov. 2010.

[8] K.Thangaraj, "Analysis and Estimation of Harmonics using Wavelet Packet Transform", *International conference on Emerging Trends in Engineering, Technology and Science (ICETETS)*, 2016.