ISSN XXXX XXXX © 2017 IJESC

Research Article Volume 7 Issue No.11

Power Quality Analysis and Improvement using Wavelet Transform and Re-Construction Filters

Dipanjli Madhukar[1], Ranjeet Pathak[2]
M.Tech Scholar[1], Assistant Professor[2]
Department of ECE
United Institute of Technology, Naini, Allahabad, India

Abstract:
Power quality is an important quality of service for the power generation and distribution. The power quality will define the quality of power supply and thus efficiency of the load power and other utilities. The power quality can be judged by the voltage or the current signals waveform in the analysis. The distortion and phase between the same can be analyzed to find the nature of the load applied to the power signal. Also, due to various natures of the networks and transmission lines, it is quite common to be having distorted power quality in the power supply. The non-linearity in the distribution and conversions can cause such distortions. Wavelet transform is an important tool in analysis of the waveform quality. In this proposed work, we have used the wavelet transform tool as the method for detection of the power quality disturbances such as swag, swell, spikes, non-linearity, and interruption. Similarly, we used db4 as mother wavelet for de-noising and detection of power quality. Here, the reconstruction filter is reused for the de-noising and the disturbance analysis. For the improvement, we are using the noise suppression algorithm along with the wavelet reconstruction filter to remove the spikes, localization and mitigation of the improvement of the power quality by the reconstruction techniques. Here, MATLAB R2013b is used as the tool for the simulation and calculation of the method and techniques and the wavelet toolbox has been used along with the signal processing toolbox for the results and validation.

Keywords: Power quality, wavelet transform, non-linearity, MATLAB, noise suppression, mother wavelet, time-domain analysis.

I. INTRODUCTION

There has been lot of researches in the field of analyzing the power quality and nature of the wave. The wavelet transform is a mathematical tool like Fourier Transform in analyzing a signal that decomposes a signal into different scales with different levels of resolution. PQ (Power Quality) has become a major concern owing to increased use of sensitive electronic equipment. In order to improve PQ problems, the detection of PQ disturbances must be carried out first. It is the fact that PQ disturbances vary in a wide range of time and frequency, which make automatic detection of PQ problems often difficult and elusive to diagnose. Hence one of the most important issues in power quality problems nowadays is how to detect these disturbance waveforms automatically in an efficient manner. These techniques detect PQ problems of waveform distortion and provide a promising tool in the field of electrical power quality problems. The improvement of power quality is based on techniques applied to detection, classification and location of disturbances. In this sense, continuous recording of disturbance signals are required, which leads to a huge volume of data to be primarily storage. In this disturbance, we can emphasize:

- Sags
- Swells
- Fluctuations
- Interruption
- Harmonic
- Transients

In this work, we have used the statistical feature extraction using 12-level wavelet decomposition of the signal. Thus, these features are used as basis for the detection and classification of the power disturbances. Similarly, wavelet reconstruction filter is used as the de-noising for the signal. Here, also the power quality improvement has been carried out using the combination of the time-domain noise suppression and the re-construction filter. Wavelet analysis and decomposition forms the basis action using DVR action by the wavelet decomposition. The results have been obtained by using the MATLAB. The wavelet toolbox and signal processing toolbox have been used for the signal processing and carrying out all the statistical analysis for the feature classification.

II. WAVELET TRASNFORM

A. *Wavelet Transform*

A wavelet is a waveform of effectively limited duration that has an average value of zero. It gives a tool for the analysis of transient, non-stationary or time varying phenomena. The basic concept in wavelet transform is to select an appropriate wavelet function “mother wavelet” and then perform analysis using shifted and dilated versions of this wavelet.

Wavelet can be chosen with very desirable frequency and time characteristics. 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 uses a number of basic functions of a 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.

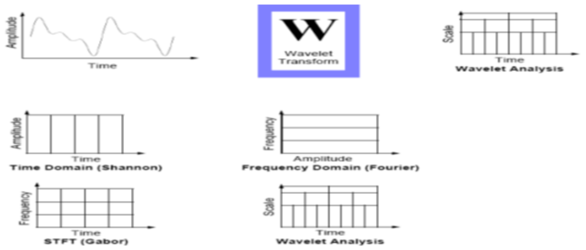

Figure.1. Wavelet Analysis

The wavelet transform can provide us with the frequency of the signals and the time associated to those frequencies, making it very convenient for its application in numerous fields. For instance, signal processing of accelerations for gait analysis, for fault detection, for design of low power pacemakers and also in ultra-wideband (UWB) wireless communications.

Discrediting of the c-τ-axis:

$$c_n = c_0^n$$
$$\tau_m = m \cdot T \cdot c_0^n$$

Leading to wavelets of the form, the discrete formula for the basis wavelet:

$$\Psi(k,n,m) = \frac{1}{\sqrt{c_0^n}} \cdot \Psi\left[\frac{k - mc_0^n}{c_0^n} T\right] = \frac{1}{\sqrt{c_0^n}} \cdot \Psi\left[\left(\frac{k}{c_0^n} - m\right) T\right]$$

Such discrete wavelets can be used for the transformation:

$$Y_{DW}(n,m) = \frac{1}{\sqrt{c_0^n}} \cdot \sum_{k=0}^{K-1} y(k) \cdot \Psi\left[\left(\frac{k}{c_0^n} - m\right) T\right]$$

B. Features of orthogonal wavelet filter banks (Reconstruction filters)

The coefficients of orthogonal filters are real numbers. The filters are of the same length and are not symmetric. The low pass filter, G_0 and the high pass filter, H_0 are related to each other by

$$H_0(z) = z^{-N} G_0(-z^{-1})$$

The two filters are alternated flip of each other. The alternating flip automatically gives double-shift orthogonality between the low pass and highpass filters, i.e., the scalar product of the filters, for a shift by two is zero. i.e.,

$$\Sigma G[k]\ H[k-2l] = 0$$

where k,ЄZ [4]. Filters that satisfy equation 2.4 are known as Conjugate Mirror Filters (CMF). Perfect reconstruction is possible with alternating flip. Also, for perfect reconstruction, the synthesis filters are identical to the analysis filters except for a time reversal. Orthogonal filters offer a high number of vanishing moments. This property is useful in many signal and image processing applications. They have regular structure which leads to easy implementation and scalable architecture.

III. PROPOSED METHODOLOGY

The proposed work can be segmented into following parts:

a. Signal De-noising
b. Signal 1-D decomposition using wavelet transform
c. Calculation of correlation coefficient Cr1 and Cr2
d. Fault detection using coefficient of correlation (Cr1 and Cr2)
e. 12-level wavelet Decomposition of signal
f. Fault type classification
g. Noise suppression in the test signal
h. Implementation of the wavelet filter and reconstruction filter for power quality improvement

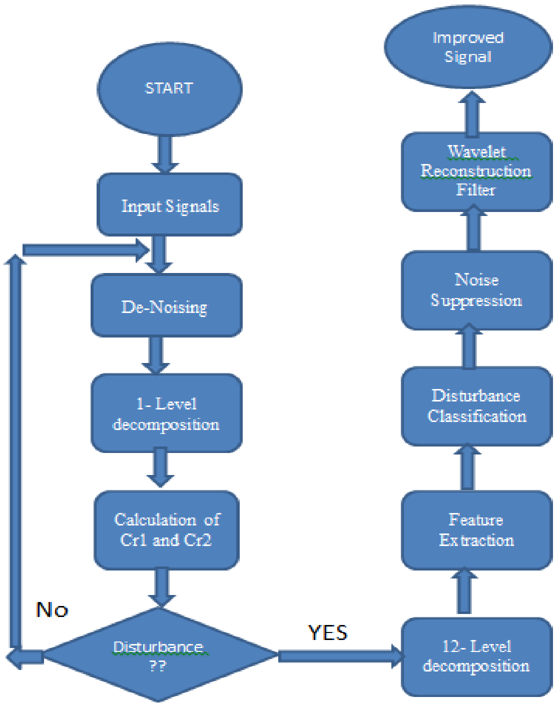

Figure.2. Proposed Methodologies

a. Signal De-noising

The test signal is decomposed 1 level for using wavelet coefficient decomposition. The wavelet decomposition has been done using the transform of the signal using desired wavelet.

b. Signal 1-D decomposition using wavelet transform

The test signal is to be decomposed into the detailed and approximate coefficient. The detailed coefficients are to be decomposed and extracted using wavelet transform tool in the MATLAB.

c. Calculation of correlation coefficient Cr1 and Cr2

The coefficients Cr1 and Cr2 is to be calculated based on the entropy calculation, average energy comparison between the coefficient of pure power signal and the test signal. The Cr1 and Cr2 are thus calculated on the basis of the ratio and difference between the entropy of the test and pure signal.

d. Fault detection using coefficient of correlation (Cr1 and Cr2)

The ideal value of the Cr1 is 1 and Cr2 is 0. If the values exceed the threshold values, the fault is said to be detected. Thus, we can detect whether disturbance/fault is present or not. If the fault is present, the signal is passed further for 12-Level decomposition. If the ratio is under the threshold, the power signal is faultless and thus no fault is said to be present.

e. 12-level wavelet Decomposition of signal

The test signal is to be decomposed into the 12-level by extracting detailed and approximate coefficient. The detailed coefficients are to be decomposed and extracted using wavelet transform tool in the MATLAB. Thus, now the 11 features to be extracted by analytical calculation of the power, energy, entropy, variance etc. and comparison are done.

FEATURE EXTRACTION

$$x_1 = \frac{Std\_absS_{d_{1,2,3}}(t)}{Mean\_absS_{d_{1,2,3}}(t)}$$

$$x_2 = \frac{Std\_absS_{d_{4,5,6}}(t)}{Mean\_absS_{d_{4,5,6}}(t)}$$

$$x_3 = \frac{Std\_absS_{d_{7,8}}(t)}{Mean\_absS_{d_{7,8}}(t)}$$

$$x_4 = \frac{Std\_absS_{d_{9,10,11,12}}(t)}{Mean\_absS_{d_{9,10,11,12}}(t)}$$

$$x_5 = Max\_absS_{d_2}(t)$$

$$x_6 = Max\_absS_{d_5}(t)$$

$$x_7 = Max\_absS_{d_8}(t)$$

$$x_8 = Max\_absS_{c_{12}}(t)$$

$$x_9 = E_{d_5}$$

$$x_{10} = E_{c12}$$

$$x_{11} = \sqrt{\frac{\sum_i |S(i)|^2}{N_s}}$$

$$Mean\_absS_{d_j}(t) = \frac{1}{2^j N_{d_j}} \sum_i |d_j(i)|$$

$$E_{d_j} = \sum_i |d_j(i)|^2$$

$$E_{c_N} = \sum_i |c_N(i)|^2$$

f. Fault type classification

After extraction of the features resulted by 12 level decomposition, all the features has been compared to the features of the pure signal. Thus, the fault classification has been done by comparison.

g. Noise suppression in the test signal

After fault classification, noise is suppressed by introducing the noise suppression techniques. The median and average filter has been implemented and test signal is to be passed on the basis of the intensity of the disturbance.

h. Implementation of the wavelet filter and reconstruction filter for power quality improvement

The coefficients obtained by the noise suppression can be differentiated into two levels- detailed and approximated coefficients. Thus, now after obtaining the coefficients, the signal is reconstructed using the reconstruction wavelet filter. Thus, the final reconstructed and improved signal has been obtained after this process.

IV. RESULTS & DISCUSSIONS

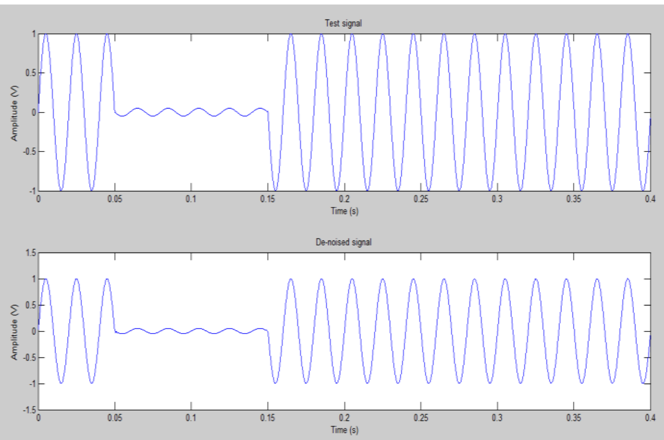

Figure. 3. DeNoising of Interruption signal Analysis

Figure 3 shows the Interruption signal and its denoising. Here, the signal is passed through the 2 level decomposition and then the reconstruction filter to denoise it.

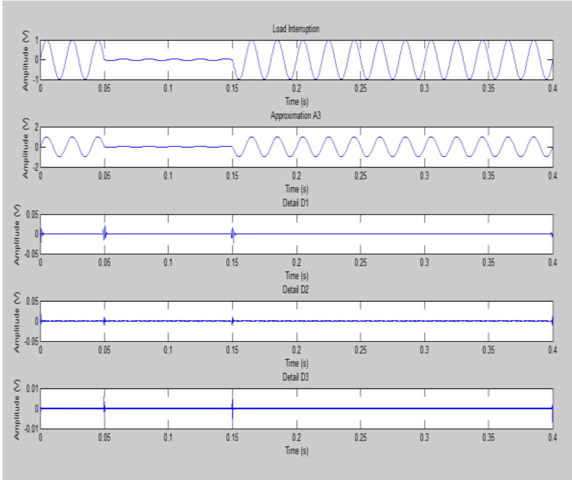

Figure.4. Two level decomposition for noise suppression technique in Interruption signal

In figure 4, the noise suppression technique has been used for suppressing the noise in the signal. The power quality is improved. Similarly, in figure 5,6,7,8 and 9 the results for various other interruption signal has been shown. Thus, we can validate the outputs of the techniques proposed by us.

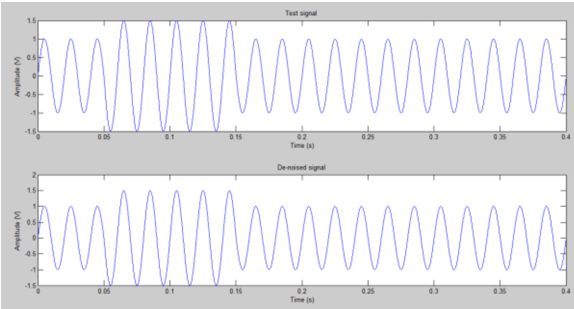

Figure. 5. DeNoising of Swell signal

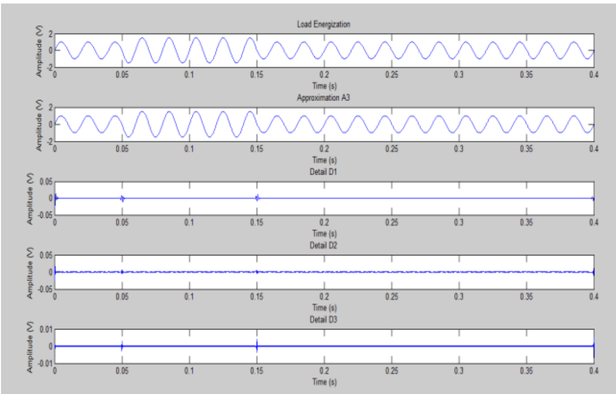

Figure.6. Two level decomposition for noise suppression technique in swell signal

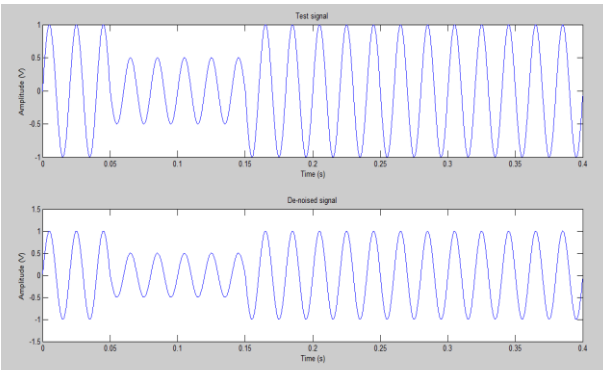

Figure.7. DeNoising of Swag signal

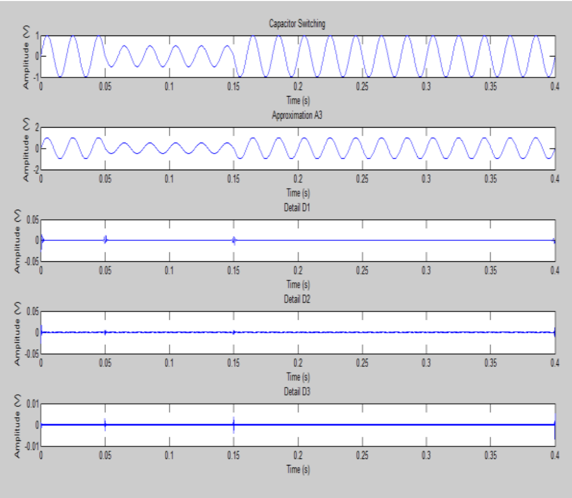

Figure.8. Two level decomposition for noise suppression technique in swag signal

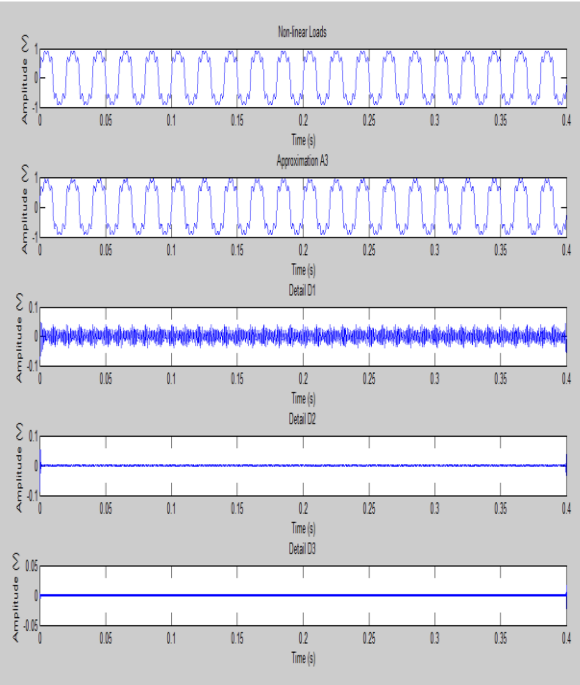

Figure.9. Two level decomposition for noise suppression technique in harmonics added signal

V. CONCLUSION

In this work, we have presented the power quality analysis and classification using the wavelet transform. The wavelet toolbox has been used for the same. The 12-level decomposition has been used. Thus, the statistical features have been shown to be for identification and classification of the power quality disturbances. The simulation results have been presented here. The results showing the output from various decomposition and filters have been shown here. We have presented the results from the reconstruction filters and filters. The proposed objectives are found to be validated. Thus, we can use the wavelet transform technique for the identification, classification and improvement for the power quality.

VI. REFERENCES

[1]. O. Poisson, P. Rioual & M. Meunier, Detection and measurement of power quality disturbances using wavelet transform, IEEE Transactions on Power Delivery, 15(3), 1039–1044, 2000.

[2]. Sathya. S & Sundararajan. D, Improved wavelet based detection of power quality events in the presence of noise, IEEE conference on circuit, power and computing technologies[ICCPCT],2015.

[3]. Jaun Ai, Zhu Wang, Xinping Zhou and Changhai Ou, Improved Wavelet Transform for noise reduction in power analysis attacks, IEEE International conference on signal processing, 10-1099,2016.

[4]. Nguyen Huu Phuc, Truong Quoc Khanh, Nguyen Nhan Bon*"DISCRETE WAVELETS TRANSFORM TECHNIQUE APPLICATION INNTIFICATION OF POWER QUALITY DISTURBANCES" **Department** of Electrical & Electronics Engineering, HCMC Univ. of Technology, Vietnam

[5]. S. Khokhar, A. A. Mohd zin, A. S. Mokhtar and NAM Ismail, MATLAB/Simulink based modelling and simulation of power quality disturbances, faculty of Electrical Engineering University Technology Malaysia, IEEE conference, 2014

[6]. A.K. Chandel, G. Guleria, and R. Chandel Classification of Power Quality Problems Using Wavelet Based Artificial Neural Network, 978-1-4244-1904-3/08/$25.00 ©2008 IEEE.

[7]. M. H. Bollen, *Understanding Power Quality Problems*, IEEE Press, 2001.

[8]. Maryam Rahmati Garousi, Mahmoud Reza Shakarami & Farhad Namdari, Detection and classification of power quality disturbances using parallel neural networks based on discrete wavelet transform, J. Electrical systems 12-1 (2016): 158-173

[9]. J. Huang, M. Negnevitsky & D. T. Nguyen, A neural-fuzzy classifier for recognition of power quality disturbances, IEEE Transactions on Power Delivery, 17, 609-616, 2002.

[10]. B. Biswal, P. K. Dash & B. K. Panigrahi, Power quality disturbance classification using fuzzy C-means algorithm and adaptive particle swarm optimization, IEEE Transactions on Industrial Electronics, 56(1), 212-220, 2009

[11]. D. Devaraj, P. Radhika, V. Subasri and R. Kanagavalli, Power quality monitoring using wavelet transform and artificial neural networks, proceedings of India International Conference on power electronics 2006.

[13]. C. Benachaiba and Ferdi, power quality improvement using Dynamic Voltage Resistor (DVR), American Journal of Applied Science 6(3): 396-400, ISSN 1546-9239, 2009.

[14]. B. T. Deshmukh, Dr. B. E. Kushare and Paramanand V. Dhote, detection of power quality disturbances using Discrete Wavelet Transform, International Journal of Advanced Research, ISSN 2278-8875, 2015.