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

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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.
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:
\[
\epsilon_n = \epsilon_0^n \\
\tau_m = m \cdot T \cdot \epsilon_0^m
\]

Leading to wavelets of the form, the discrete formula for the basis wavelet:
\[
\psi(k, n, m) = \frac{1}{\sqrt{\epsilon_0^m}} \cdot \psi \left[ k - \frac{m \epsilon_0^m}{\epsilon_0^n} T \right] = \frac{1}{\sqrt{\epsilon_0^m}} \cdot \psi \left[ \left( \frac{k}{\epsilon_0^m} - m \right) T \right]
\]

Such discrete wavelets can be used for the transformation:
\[
Y_{DWT}(n, m) = \frac{1}{\sqrt{\epsilon_0^m}} \cdot \sum_{k=-\infty}^{\infty} y(k) \cdot \psi \left[ \left( \frac{k}{\epsilon_0^m} - m \right) T \right]
\]

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, G₀ and the high pass filter, H₀ 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
f. Fault type classification
After extraction of the features resulted by 12 level decomposition, all the features have 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
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


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