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Detection of Power Quality Disturbances Using Discrete Wavelet Transform

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ABSTRACT: Identification and classification of voltage and current disturbances in power systems are important tasks in the monitoring and protection of power system. Most power quality disturbances are non-stationary and transitory and the detection and classification have proved to be very demanding. The concept of discrete wavelet transform for feature extraction of power quality disturbance signal as a powerful tool for detecting of power quality disturbance. This paper employs a discrete wavelet transform (DWT) to have a better power quality disturbance detection accuracy. The disturbances of interest include voltage sag, voltage swell, transient, fluctuation, interruption and normal. The discrete wavelet transform has been used to detect and analyse the power quality disturbances. The disturbances of interest includes voltage sag, voltage swell, transient, interruption, fluctuation, and normal disturbance. The system is modelled using MATLAB Simulink. The disturbance voltage waveform is obtained from disturbance generation model. The DWT has been chosen for feature extraction. The outputs of the feature extraction are the DWT coefficients (detailed and approximate) represents the power quality disturbance signal at different levels in time and frequency domain.

KEYWORDS: Power quality, disturbance detection, wavelet transform, signal decomposition.

I. INTRODUCTION

THE scarceness of power quality (PQ) experts in the electric power industry poses a problem in handling the huge amount of data gathered by the distributed PQ monitoring systems. Besides that, knowledge about PQ is dispersed and fragmented [1]. The disturbance waveforms contain serious imprecision of data and directly provides very little information on PQ, making conventional programs fail to identify any PQ problems. Existing recognition methods need much improvement in terms of their versatility, reliability and accuracy in order to process the disturbance waveforms. Complex PQ disturbances are non-stationary and transient by nature and points of sharp variation such as singularities in transient signals usually carry the most important information about the disturbances and it is vital to efficiently extract and interpret this information from the disturbance waveforms. Discrete wavelet transform (DWT) have been proven to be very efficient in signal analysis [2]. Apart from filtering noise, it accurately detects sharp changes and discontinuities in PQ disturbance signals, and extracts their characteristic features for subsequent disturbance identification. 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. Santoso et al [4] proposed wavelet transform technique for the detection and localization of the actual power quality disturbances. They explored the potential of wavelet transform as a new tool for automatically classifying power quality disturbances. Heydt and Galli [5] proposed wavelet techniques for the identification of the power system transient signals. Fuzzy logic control technique has been discussed by Hiyama et al [3] to enhance power system stability using static VAR compensator. The proposed control scheme is simple and suitable for on-line implementation using a microcontroller. Santoso et al [6] combined wavelet transform with Fourier transform for the characterization of the power quality events. The Fourier transform has been used to characterize steady state phenomena, whereas the wavelet transform has been applied to transient phenomena. Olivier et al [7] investigated the use of a continuous wavelet transform to detect and analyze voltage sags and transients. They developed an efficient and simple algorithm for detecting and measuring power quality analysis. A digital signal processing architecture capable of simultaneous and automated detection and classification of transient signals has been developed by Angrisani et al [8].

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The basic unit of the architecture is the wavelet network which combines the ability of the wavelet transform for analysing non stationary signals with the classification capability of artificial neural networks. Styvaktakis et al [9] developed an expert system to classify different types of power system events and offer useful information in terms of power quality. Huang et al [10] presented a neural-fuzzy technology based classifier for the recognition of power quality disturbances. The proposed recognition system provides a promising approach applicable in power quality monitoring. Driesen and Belmans [11] proposed further alternatives for power quantification based on formulations and time frequency domain described by wavelet bases. They used both the real and complex valued wavelets. He and Starzyk [12] proposed a novel approach for power quality disturbances classification based on wavelet transform and self-organizing learning array system. Wavelet transform has been utilized here to extract feature vectors for various power quality disturbances based on multi resolution analysis. Lin and Wang [13] proposed another model for power quality detection for power system disturbances using adaptive wavelet networks. Megahed [14] et al presented a new method for the boundary protection and fault classification of series compensated transmission lines using discrete wavelet transform. An effective algorithm for arcing fault detection for distribution network with the application of wavelet transform technique has been presented by Michalik et al [15]. Brahma [16] introduces wavelet transform to reliably and quickly detect any fault during a power swing. A logic block based on the wavelet transform has been developed. Another expert system developed by Reaz et al [17] which employs a different type of univariate randomly optimized neural network combined with discrete wavelet transform and fuzzy logic to have better power quality disturbance classification accuracy. Elkalashy et al [18] used DWTs to detect high impedance faults due to leaning trees. Wireless sensors have been considered for processing the DWTs. Mishra et al [19] presented an S transform based probabilistic neural network classifier for the recognition of power quality disturbances. The Wavelet Transform is a powerful tool for detection of power quality problems. This paper deals with the use of DWT to detect and analyse voltage sag, swell, transients, fluctuation, Interruption and normal disturbances.

II. POWER SYSTEM NETWORK SIMULATION

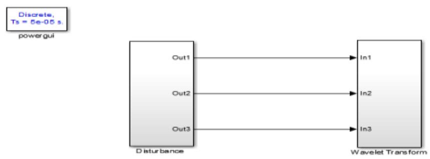

Fig. 1.Simulink Model

Fig.1.shows the Simulink model consists of disturbance generating model and wavelet transform. Disturbance model Includes different types of power quality disturbances like voltage sag, voltage swell, transient, interruption, fluctuation and normal are described in combined Simulink model to detect the power quality disturbances.

A. Disturbance Generation

Fig.1 shows the disturbance generation model fed to the wavelet transform as the input. In waveform generation, five types of disturbances that include transients, sag, swell, interruption, and fluctuation, are randomly superimposed on the normal waveform at a rate in accordance with their relative occurring frequencies. In this research, the power frequency chosen was 50 Hz. The disturbance waveform consists of five cycles of samples of voltage signals (in per unit).

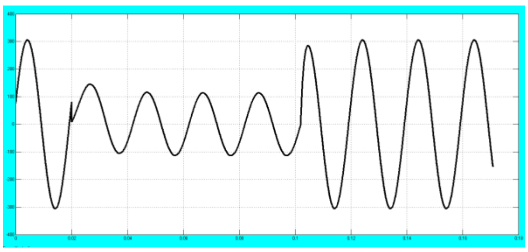

Fig.2.Voltage sag event on phase A

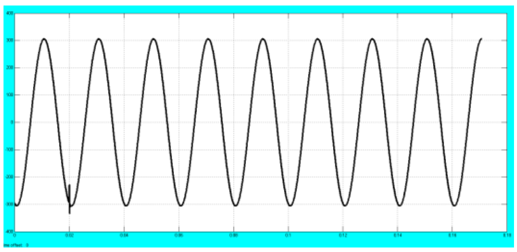

Fig.3. Transient event on phase B.

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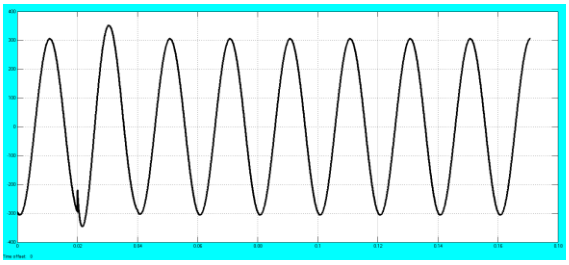

Fig.4. Fluctuation event on phase B.

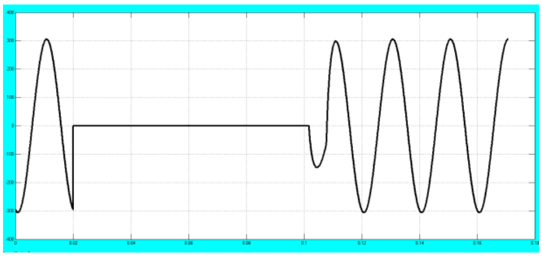

Fig.5. Interruption event on phase B

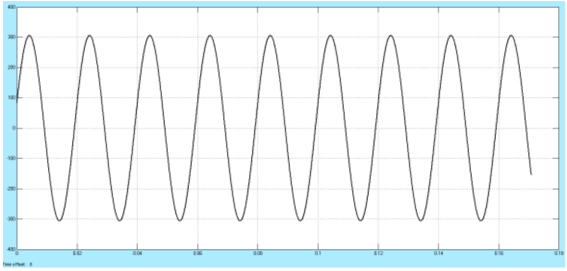

Fig.6. Normal event on phase B.

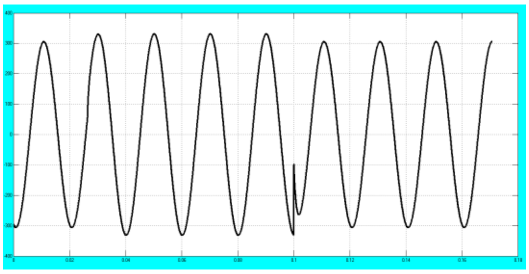

Fig.7. Swell event on phase B.

B.Feature Extraction Using DWT

The first step in the analysis of PQ disturbances is their detection and consists of two steps: feature extraction and classification that is performed based on the model shown in Fig.1 (Block diagram of the detection of disturbance system.) This paper presents multi resolution signal decomposition technique as a powerful tool for detecting and classifying disturbances in the electrical distribution system. The proposed technique will deal with the problem not only in time domain or frequency domain, but in a wavelet domain which covers both the time and frequency domains. Multi resolution signal decomposition technique can detect and diagnose defects and provide early warning of impending power quality problems. Using the properties of the wavelet and the features in the decomposed waveform one will have the ability to extract important information from the distorted signal at different resolution levels and classify the types of disturbance. Here the signals of disturbance waveform has been analysed with Discrete Wavelet Transform (DWT). Fig. 8, 9, 10,11,12,13 and 14 shows the analysis of the signal of sag. Transient, fluctuation, interruption, normal and swell disturbance by wavelet Db4. As far as the detection and the localization are concerned the first inner decomposition level of the signal (CD1) is normally adequate to detect and localize any disturbance in the signal.

Table 1.Sub-bands of DWT Transform Coefficient

Transform Coefficients	Frequency Range
CD1	64f1-128f1
CD2	32f1-64f1
CD3	16f1-32f1
CD4	8f1-16f1
CD5	4f1-8f1
CA5	0-4f1

However other coarser resolution levels are used to extract more features which can help in the classification process. There are few wavelet transform coefficients with high values while the rest has zero value.

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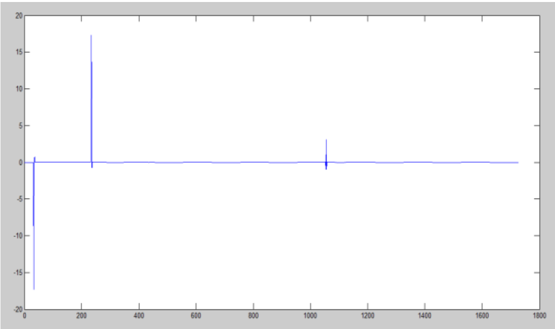

Fig.8. CD1 coefficients of DWT of sag.

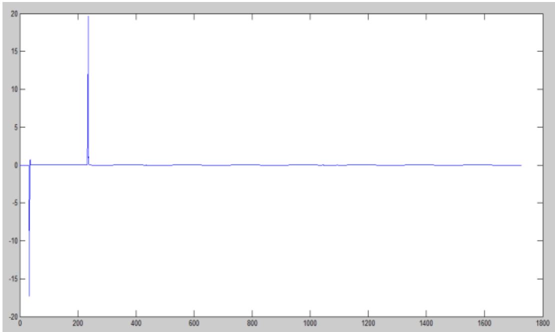

Fig.9. CD1 coefficients of DWT of transient.

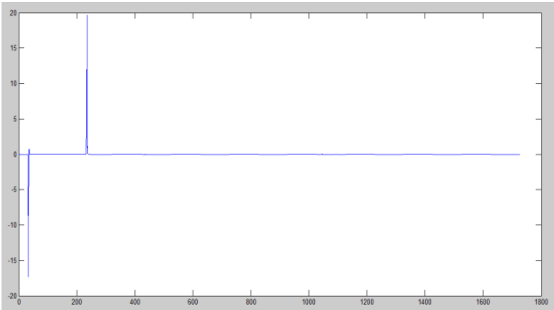

Fig.10. CD1 coefficient of DWT of fluctuation.

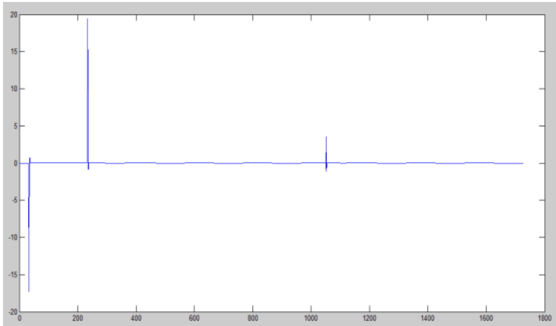

Fig.11. CD1 coefficient of DWT of interruption.

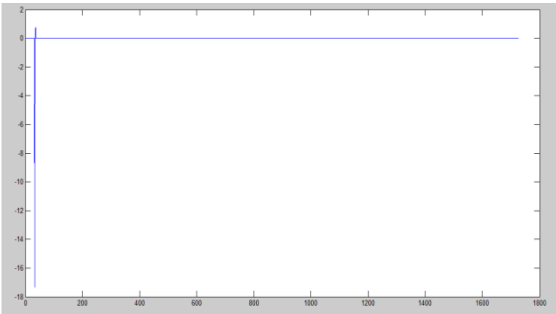

Fig.12. CD1 coefficient of DWT of normal.

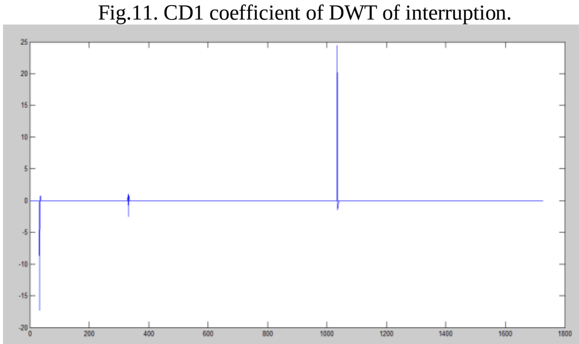

Fig.13. CD1 coefficient of DWT of swell.

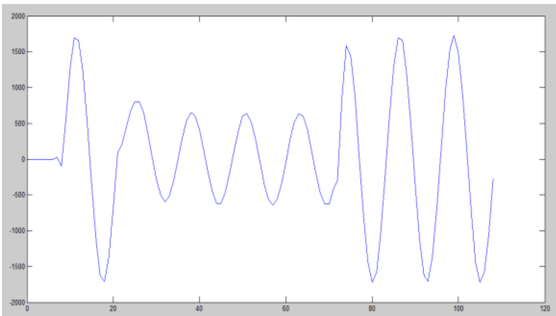

Fig.14.CA5 DWT coefficient of sag.

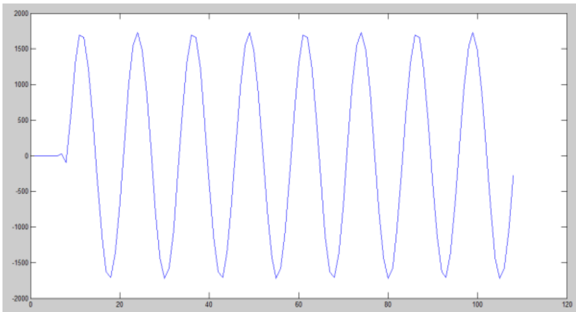

Fig.15. CA5 DWT coefficient of transient

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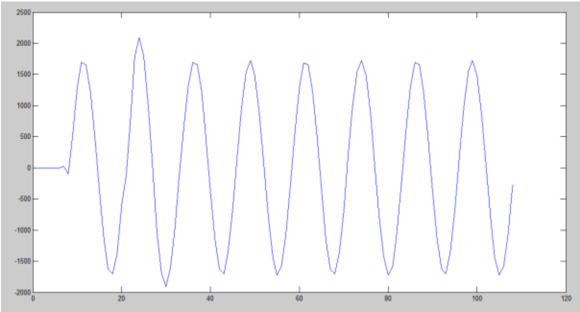

FIG.16. CA5 DWT coefficient of fluctuation.

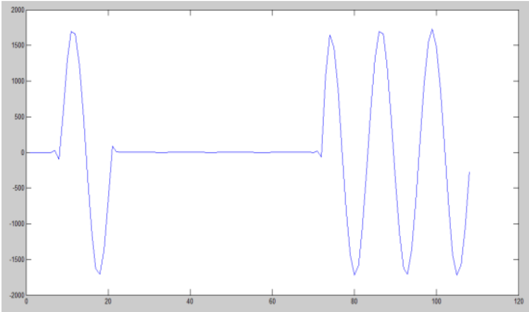

Fig.17.CA5 DWT coefficient of interruption.

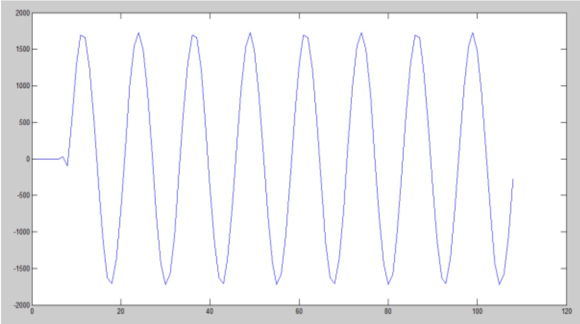

Fig. 18.CA5 DWT coefficient of normal.

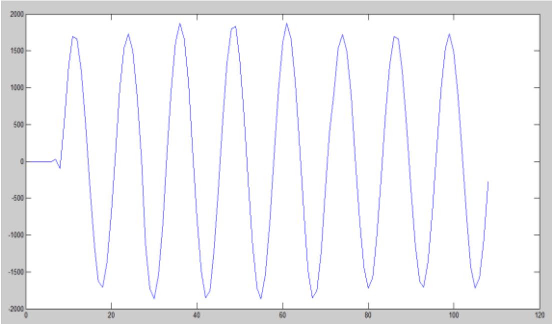

Fig.19.CA5 DWT coefficient of swell.

The wavelet transform coefficients with high values indicate the power quality disturbance events and the exact location of the disturbance. The other part of the decomposed signal of detail CD1 is smooth indicating that the signal follows some regular patterns in those periods without having any electrical noise. Detail CD1shows the exact location of the disturbance. The approximation CA5reveals the regular pattern of the signal. The details from level 1 to 4 are shown and the instant of the occurrence of the disturbance can easily be detected from the Wavelet analysis.

III. CONCLUSION

Nowadays the detection and classification of transient phenomena in the power supply lines are of ever growing importance. Correct detection of undesired transient disturbances is essential for electrical utilities. It is also important for customers principally in verifying that the received power is above the level of quality defined by the service contract. The currently available measurement equipment which are capable of collecting large amounts of data from the monitored power signals, provides the possibility of detecting only those transient disturbances that cause the rms value of these signals to exceed a fixed threshold. A simple report giving details on disturbance statistics is normally available to the user at the end of the recording. Only very sophisticated instruments can classify the detected transient disturbances onthe basis of their duration as well as estimated amplitude. No automated classification depending on their shape is allowed. Hence power quality engineers can only visually inspect the records in order to select the disturbances and to perform a proper classification. Unfortunately the volume of the collected data is so large that the visual inspection becomes impractical and disturbance detection methods are in considerable demand.

The Wavelet Transform for feature extraction of power disturbance signal is a powerful tool for detection of power quality problems. It has been discussed in detail in the paper the application of Discrete Wavelet Transform for the detection of power quality disturbances.

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