I J C T A, 9(2) 2016, pp. 847-857

Traverse Dyadic Wavelets in Stationary and Non Stationary Stray Flux Signatures for Power Quality Disturbances - Analysis

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ABSTRACT

Power quality issue is the major problem in all Electrical Equipment. Normally, power quality issue is analyzed using current or vibration signals in real time environment .Till now, the current or vibration signal is analyzed using FFT, DWT & STFT Transforms for detecting the power qualities .The shift invariance property in DWT is the drawback, which lead to shrink between the scales. The shift invariance property will not able to analyze the low frequency power disturbances. A novel approach based on traverse dyadic wavelet transform is used for detecting the stationary and non-stationary signals with low and high frequency level disturbances from flux signatures. From the micro grid Experimental set up, stray flux signatures signals under different fault condition is analysed using traverse mother wavelet dyadic transform. From results, we conclude that the dyadic signals are most suited for power factor correction decision making.

Keywords: Dyadic wavelet, flux signatures, stationary and non-stationary signals.

I. INTRODUCTION

Today's world is very much concerned to reduce greenhouse gas emissions from the conventional thermal power plants as cutting down emissions from transport and heating sector may not be realistic in the near future. To reduce pollution from electrical power sources the world is now marching towards usage of renewable energy sources. These sources being small in capacity are mostly connected at the distribution voltage level. This indirectly reduces transmission and distribution losses since the sources are around the load. This distribution system having small scale energy sources is called as a micro grid or active distribution network.

Micro grid operates generally in a grid connected mode. However circumstances such as fault, voltage sag and large frequency oscillations in the main grid may force the active distribution network to be disconnected from the main grid and operate as an isolated micro grid. During this isolation there will be changes in power output from the controllable micro sources which are to be regulated properly to have a stable operation in regard to power balance and frequency of operation within the isolated micro grid. To bridge the gap between the loads consumption and power produced by the renewable energy sources, the controllable sources: diesel generator, combine cycle gas turbine based system, fuel cell, battery and wind etc. are used as possible alternate solutions, if available in the micro grid.

The regulation leads to oscillations in the frequency. These oscillations should be damped out using proper controller design. Oscillations (or) disturbances need to be identified, in order to monitor the micro level disturbances in the delivered output. Hence we introduce **Traverse Dyadic Wavelet** transform [1] for identifying level of disturbances in the delivered output power from the micro grid [2] [3]. The disturbances studied under different conditions can adopted as **"patterns or signatures"** for each disturbance.

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II. SYSTEM DESCRIPTION

Search coils are employed to capture flux signals from inside and outside the machine. Such coils are able to provide electrical *"quality" signatures* [2] [3] sensitive to conditions which alter the electrical characteristics. The voltage pick-up of such coils is directly proportional to the rate of change of the flux. The occurrence of power quality disturbances in an electrical machine results in a change in the air-gap space harmonic distribution. A search coil is able to detect the time harmonics but is not able to capture the space harmonics. Space harmonics in the stator cause time harmonics in a rotating rotor. By choosing the search coil properly, the number of space harmonics to be monitored may be restricted.

In the industrial environment, the flux measurements are preferably taken with the flux coil placed outboard in the axial direction, since it is easier to take readings in the *axial* direction in order to ensure the repeatability of the flux coil position. On the other hand, the recommended mounting location for some monitoring units is *radial* for the optimal location to detect temperature and vibration (Burnett 2002).

The *axial* flux measurements are potential method for monitoring the condition of the stator and rotor winding of motors during operation. The axial flux analysis has also been found to be able to identify rotor asymmetries, shaft misalignments, and bearing faults. (Tavner and Penman 1987, Vas 1993). The technique of measuring the axial leakage flux is simple and non-invasive. All that is required is a search coil placed concentrically with the drive shaft of the motor. Some authors claim that, typically, there is sufficient axial leakage flux that it is possible to mount the coil, or coils, external to the machine case (Kokko 2003). End winding leakage fluxes are the main cause of the axial leakage flux, which is measured using axial leakage flux measurement.

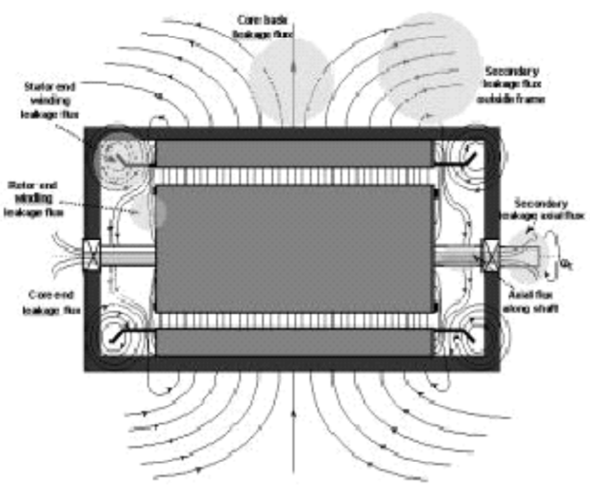


Figure 1: Schematic of flux regions used for condition monitoring of electrical machines (Thomson 1999)

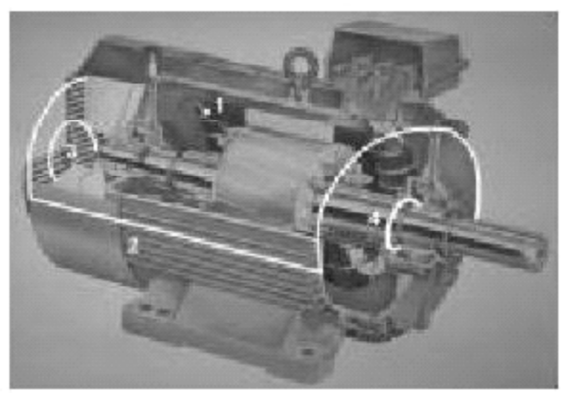


Figure 2: Search coils used for the electromagnetic flux monitoring.

In this paper, the search coils shown in Fig. 1, 2 were studied both by means of measurements (carried out for 11-KVA Cage Induction Generator) and simulations in order to find out their ability to sense disturbance, two external search coil formed of each 200 turns on former used as current sensor to pick up the radial and axial flux under various condition of load and no load. Search coils will sense the electromagnetic flux harmonics of the order "$p\pm1$", which provides the flux signatures for detecting the low and high frequency disturbances for review analysis.

The block diagram of Micro grid generating unit with flux sensor interfaced has been proposed in this paper as shown in Fig. 3. The proposed system is designed with single shaft micro grid, has been considered and Modeled [3] by several authors. This results in high speed high power generation.

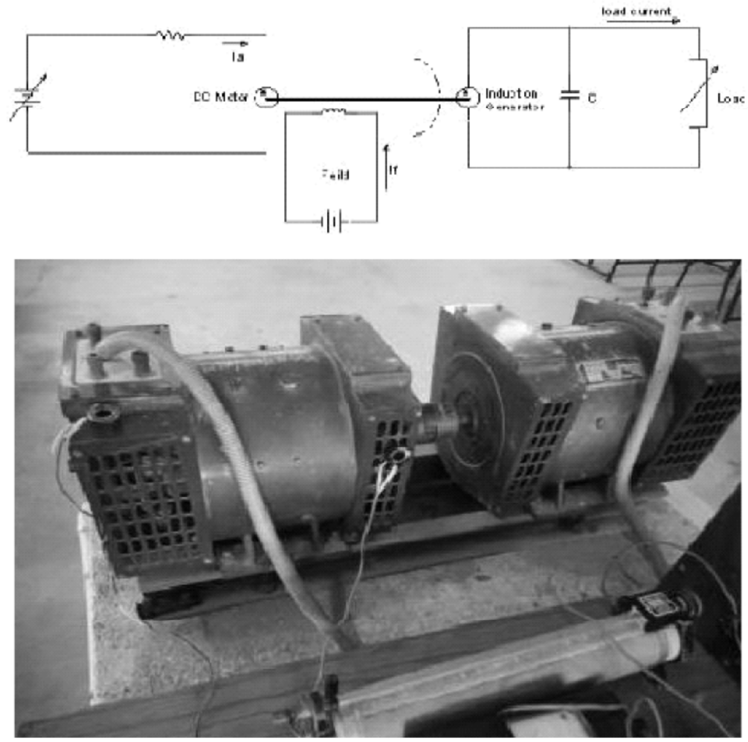


Figure 3: The Experimental Setup

A three phase induction generator with a nominal power of 1500W 440v 50Hz frequency is employed as the system for study. The system parameters are

Stator Resistance R1 =0.0045Ω

Stator Leakage Reactance X1 =0.0513 Ω

Magnetizing Reactance X_m =2.2633 Ω Rotor resistance R2= 0.0066 Ω

III. WAVELET TRANSFORM AND DISTURBANCE ANALYSIS

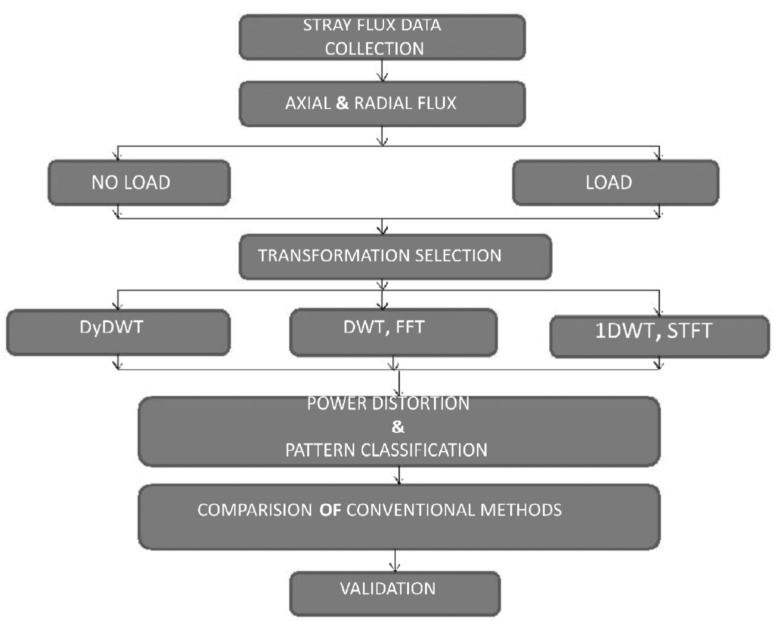


Figure 4: Flow of the proposed flux signature prediction method

Wavelet transform is a recent signal processing tool which is widely being used for disturbance detection in Power Quality. The Wavelet Transformation approach prepares a window adjusts to give proper resolutions of both time and frequency [1] Wavelets, little wave like functions, are used to transform the signal under investigation into another representation which presents the signal information form.This transformation of the signal is known as Wavelet Transform. WT. [1] .The importance of transformation is well studied for possible combination of results, which lead to decision making in power quality [10] [11].

The flow chart in this context describes the work carried out for analysis of power quality disturbances[3] using various transformation techniques such as Dy-DWT, DWT, 1-DWT.The investigation followed, as flux from the induction generator in different load conditions collected (axial and radial) by flux sensors are monitored through SIGVIEW software tool, where the variations are identified. The variation in the signal output (co-effients) are analysed through MATLAB software. The coefficients are tabulated for decision making, such as sag, swell, total harmonic distortion (THD).

IV. SIGNAL PROCESSING TECHNIQUE

The purpose of this paper is to introduce to the power engineering community a powerful new method for transient data capture and analysis to identify major power quality issues. The wavelet transform, which has received considerable interest in fields such as acoustics, voice communications, and seismic, is proposed as a fast and effective means of analyzing voltage and current waveforms recorded during power system disturbances.

In particular, the ability of wavelets to focus on short time intervals for high-frequency components and long intervals for low-frequency components improves the analysis of signals with localized impulses and oscillations, particularly in the presence of a fundamental and low-order harmonics.

Temporal analysis is performed with a contracted, high frequency version of prototype wavelet, while frequency analysis is performed with a dilated, low frequency version of the prototype wavelet. Because the original signal or function can be represented in terms of a wavelet expansion using coefficients in a linear combination of the wavelet functions, data operations can be performed using just the corresponding wavelet coefficients. There are several types of wavelet transforms. Depending on the application, one may be preferred to the others. For a continuous input signal, the time and scale parameters can be continuous, leading to the continuous wavelet transform. On the other hand, the discrete wavelet transform can also be defined for discrete time signals.

In the case of wavelet transforms, the original domain is the time domain. The transformation process from time domain to time scale domain is a wavelet transform, technically known as signal decomposition because a given signal is decomposed into several other signals with different levels of resolution. From these decomposed signals, it is possible to recover the original time domain signal without losing any information. This reverse process is called the inverse wavelet transform or signal reconstruction. To illustrate the transform, let S(t) be the time domain signal to be decomposed or analyzed. The dyadic wavelet transform of S(t) is defined in equation (1) as follows:

$$\text{DWT } \O S(m,n) = 2^{-\frac{m}{2}} \int_{-\infty}^{\infty} s(t)\, \O * \left(\frac{t - n2^m}{2^m} \right) dt \tag{1}$$

where the asterisk denotes a complex conjugate, m and n are scale and time shift parameters, respectively, and Ø(t) is a given basis function (Mother wavelet).

V. METHODOLOGY

Locating the time at which the disturbances occur is one of the capabilities of the wavelet transform. To identify this time we could apply the following steps:

1. Generate a set of test signals with known disturbance beginning and duration times.
2. Apply the different wavelet transforms of the MATLAB to this set of signals.
3. Locate the exact instance of disturbance by means of a visual inspection of the wavelet coefficients.

VI. CONDITIONS OF MONITORING

No-load test

For the no-load tests, the motor was supplied at rated voltage, and operated at rated speed; with this initial the flux sensors have been placed at different location to capture the various positioned harmonic components. The sampling frequency for Dyadic wavelet transform is about 2ms .with this condition carefulness is made to capture different sign signals.

Load Condition

For the load tests, the motor was supplied at rated voltage and the shaft coupled to AC generator. The motor was loaded to about 95% of its rated power. A resume of the harmonics which present the highest level of significance is captured.

Heavy Load Condition

For the heavy load tests, the DC motor was supplied at rated voltage and the shaft coupled to Induction generator. The motor was loaded to about 100% of its rated power (Resistive load). A resume of the harmonics which present the highest level of significance is captured. It is evident that most of the harmonics which are efficient in detecting stator shorts for the no-load motor are even valid to detect the same fault on the loaded motoring conditions. Best results have been diagnosed under different operating conditions.

VII. STUDY OF CASES

1. Detecting and localizing in time a disturbance

The choice of the wavelet to be used is a topic of considerable Research, since there is no rule to be applied. Some basic aspects can help us to select a suitable wavelet function including the similarity of the signals with the wavelet functions, and deep analyses of data with known anomalies indicating the phenomena. The so-called "Haar "Wavelet was assumed as the base function in this work. This function was chosen, based on previous studies that support its robustness and suitability for fault detection evaluation [6]–[11].

The wavelet adopted in this study is the "Haar wavelet" shows in fig.5, is used as the reference signal for the act of comparison, visual inspection and decision making. Different Wavelet families are available

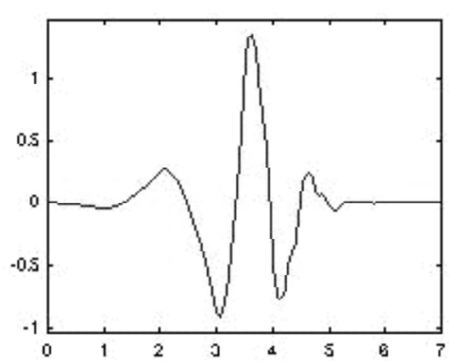


Figure 5: "Haar"wavelet

in the MATLAB software are used to analyze the signal disturbance .we apply a one scale wavelet transform to identify the various levels of disturbances.

7.2. Identifying the Disturbance

In order to try to identify the type of disturbance present in the voltage signal of Fig. 6, the step 1, 2 has to be work out. In this step, the deviations in the energy level by means of a visual inspection of the wavelet coefficients are studied.

VIII. RESULTS

The fig 6.shows different "curve families" of power quality disturbances .Each one of these curves were obtained by different conditions of load for analyzing the power quality disturbance to group them in a category. The amplitude and the shape of the curve have vast variations due to a fact that the intensity of the disturbances can change in accordance with the point of measurement .Each curve has different signature that can be adopted for the power quality disturbance recognition .This approach can be helpful, to classify the severity of disturbance as well as to correct it

We have generated voltage signal with a known a dyadic wavelet transformation. A number of test signal with different sag level, varying duration, occurring at varying instances have been generated and result of first level wavelet transform of various families are compared. It was evident from the result the Haar wavelet ('Haar') is accurate in locating exact instance of occurrence and duration of sag.

As Dyadic wavelet has been used, the six higher bands correspond to frequency ranges were analysed to detect the disturbance range and to categorize them according to level of disturbance.

49-90 Hz (1 band),

90-180 Hz (2nd band),

180-360 Hz (3rd band),

360-720 Hz (4th band),

720-1440 Hz (5th band),

1440-2880 Hz (6th band)

2880-5760 Hz (7th band).

Wavelet Coefficients (WC) is calculated which is used to identify and detect different kinds of disturbances. WC with high values indicates Power Quality disturbances, while smaller values are Indicative of Electrical Noise.

8.1. Analysis of signal in both time domain and frequency domain

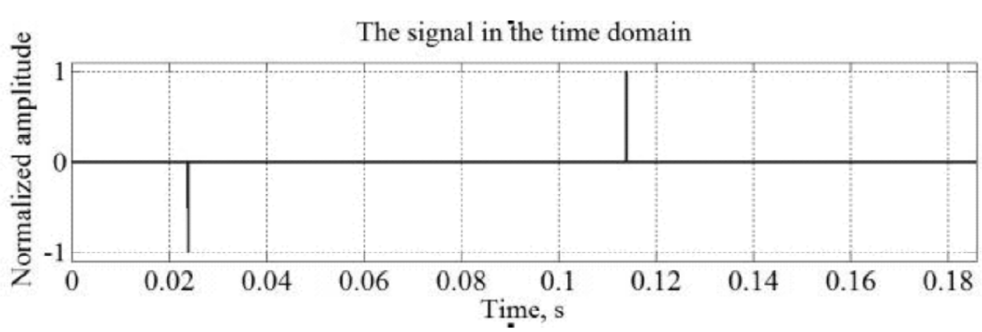


Figure 6: Analysis of signal in time domain

Under resistive load condition, the estimation of the Instantaneous Frequency by suitable processing technique, the transversal stray flux (PTSF) can provide the necessary information for perceiving the fault instant. However, a risk of false detection has been experienced. Indeed, an undesirable frequency peak has been observed.

The voltage deviates at the interval of 0.03 sec and 0.17sec, this spikes are indication of frequency deviations in the Normalized spectrum. The same deviations are also identified to as the load (Resistive) in the induction generator is not maintained constant. This deviation can be categorized as voltage sag.

Transformation in both time domain and frequency domain

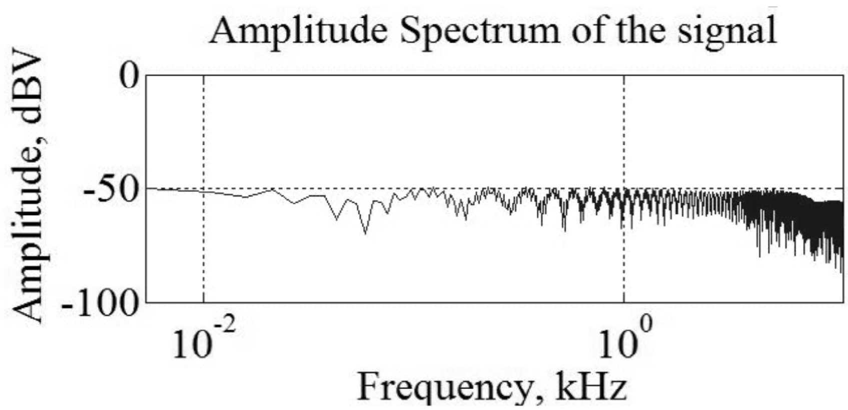


Figure 7: Analysis of signal in time and frequency domain

The result above predicts the deviation of the voltage in both time as well as frequency .From this we can conclude that there is a deviation of voltage in terms of amplitude and time.

Voltage deviation indicates the sag, as the frequency deviates and the amplitude reduces.

We observe that the estimated frequency is wandering into a range bounded by about 10^{-2} and 10^{0} Hz. Yet, the plot is marked by the attendance of many amplitude peaks.

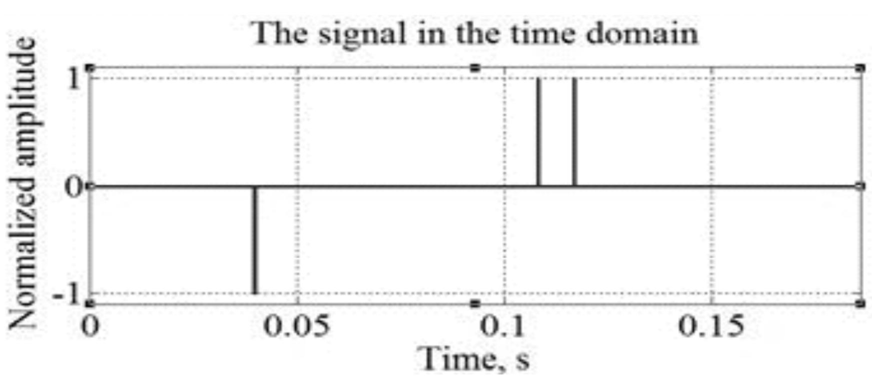


Figure 8: Analysis of signal in time domain

Table 1 discuss about the statistical analysis (Miu, sigma, crest factor) of different wavelet transformations .From this the coefficients of Dyadic wavelet and discrete wavelet are compared, where the minute variation is greatly influenced by Dyadic wavelets transform. The values of ó for dyadic is0.03492 and DWT are 0.03491 where the variation is a minimum, but for the sake of understanding is evident that minute variations are identified. Similarly the crest factor 29.1339DB is identified which is of the lower order which when compared to discrete wavelet transform.

Besides the evaluation of disturbance coefficients, it's an alternative to present the disturbance severity in terms of graphical solutions. Here we provide the range of disturbance for different load conditions. The bar graph represents the disturbance level after decomposition of data obtained by dyadic wavelet transformations.

The result in figure 8 above overcomes a risk of false detection has been experienced. Indeed, an desirable disturbance is again occurred in the system with respect to the voltage deviation .Here the deviation occurs at the range of0.05s to 0.1s ,this is more peculiar to identify the same disturbance with variation in the load (resistive). Hence one Can conclude that effectiveness of this monitoring approach Has been proven that Dyadic wavelet transformation is best suited for power quality disturbance analysis.

Table 1
Wavelet coefficients in various transform conditions

S.No	*Condition*	*Sigma (σ)*	*Miu (μ)*	*Crest factor (Db)*
1.	Dyadic wavelet (Radial flux and axial flux in two channel) Load condition	0.034942	0.00024414	29.1339 Db
2.	FFT (Radial flux and axial flux in two channel Load condition	0.03125	0.00048828	30.103 Db
3.	STFT(Radial flux and axial flux in two channel (Load condition)	0.03240	0.0004876	31.100 Db
4.	DWT (Radial flux and axial flux in two channel (Load condition)	0.03491	0.00024512	31.122 Db

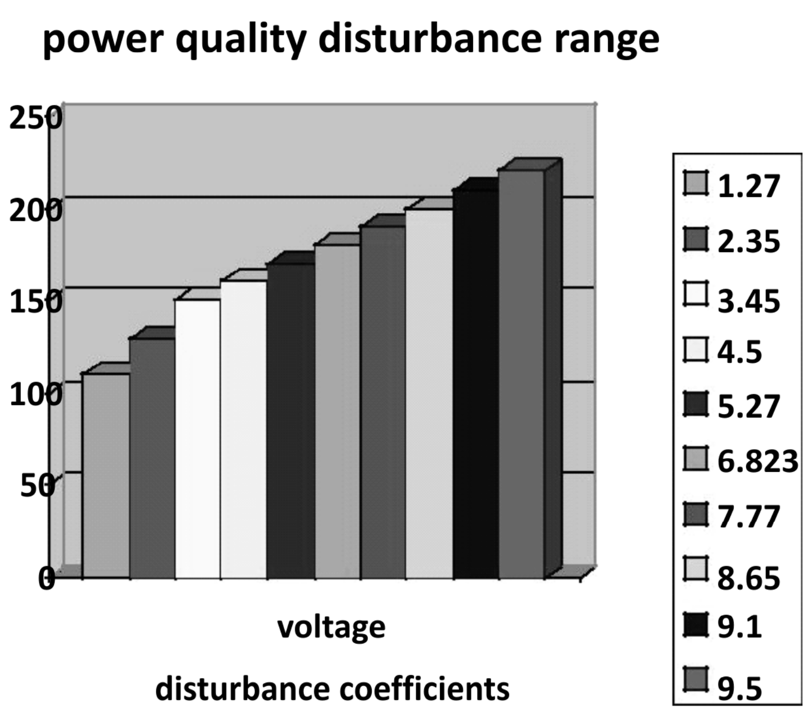


Figure 9: Graphical representation of the wavelet

Table 2
Frequency Bands under various load conditions

<table>
<tr><td>Dyadic wavelet
(Radial flux and axial flux in two channel under the load condition) The amplitude of the generated wave is reduced which in identified as sag in the power system .The flux signature is well identified with Voltage signal for high frequency spike. However, the exact time of occurrence is revealed only by WC, which in turn determines the nature of flux with outcome as disturbance or noise

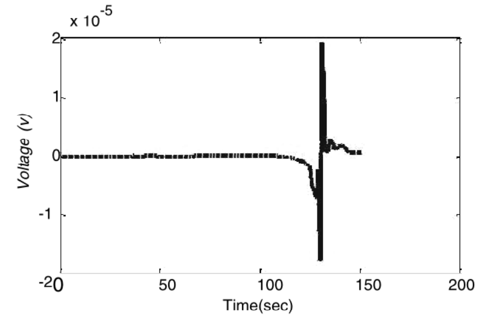
90-180 Hz (2nd band)</td><td>

Fig .10.1a</td></tr>
<tr><td>Dyadic wavelet
(Radial flux and axial flux in two channel under the load condition) The amplitude of the generated wave is reduced which in identified as sag in the power system .A voltage waveform signal with 2 sharp spikes over very short duration. However, the exact time of occurrence is revealed only by WC.

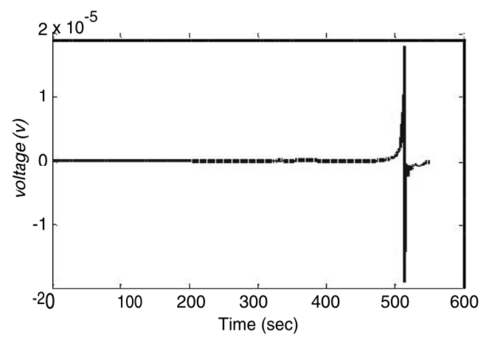
360-720 Hz (4th band),</td><td>

Fig .10.1b</td></tr>
<tr><td>Dyadic wavelet
(Radial flux and axial flux in two channel under the load condition) The amplitude of the generated wave is reduced which in identified as sag in the power system **A** high frequency harmonic (1000-15OOHz) has been detected in the dyadic transformation. However, the exact time of occurrence is revealed only by WC which could be useful in finding out the cause of such high frequency distortion. This is an added advantage of using dyadic wavelet analysis as compared to the FFT

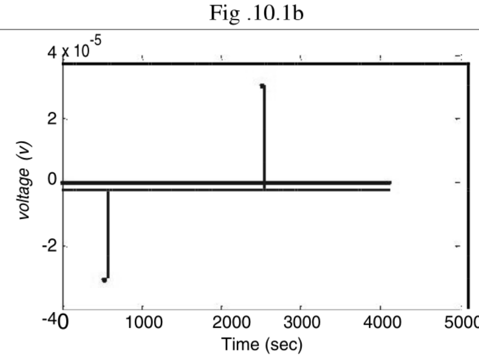
1440-2880 Hz (6th band)</td><td>

Fig. 10.1c</td></tr>
<tr><td>Dyadic wavelet

(Radial flux and axial flux in two channel under the load condition) The amplitude of the generated wave is reduced which in identified as sag in the power system. **A** high frequency harmonic **(1000-15OOHz)** has been detected in the dyadic transformation . However, the exact time of occurrence is revealed only by WC which could be useful in finding out the cause of such high frequency distortion. This is an added advantage of using dyadic wavelet analysis as compared to the FFT

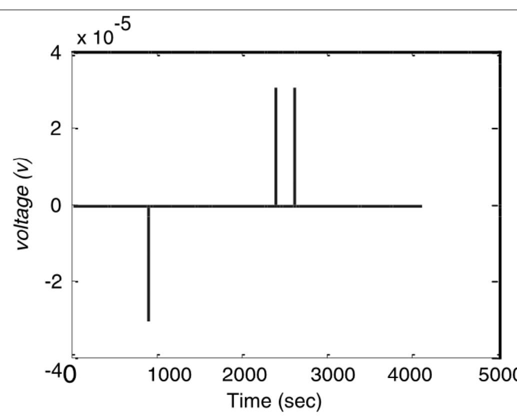
1440-2880 Hz (6th band)</td><td>

Fig .10.1d</td></tr>
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As mentioned earlier the proposed technique has the advantage to discard the need to access to the load line for picking the current. In addition, satisfactory results have been obtained by the use of low-cost sensors (simple search coil) for detecting stationary and non-stationary signals with low and high frequency level disturbances from flux signatures. The categorized results are tabulated which clearly depicts the frequency deviation investigated under various wavelet conditions.

IX. CONCLUSION

As per faradays law of electromagnetism, the generated voltage give rise to the load currents in time derivative of the flux crossing the stator coils. Based on this, if any changes occurs in generating point it would affect the normal operating condition, which reflects on the embraced fluxes before spreading to affect main outputs. Based on this we proposed a method to identify the flux deviation (leakage flux) which would result in power quality problems. compared to other conventional, techniques, the main advantage of our proposed methodology is low cost implementation, cheap noninvasive sensor (search coils) ,and no need to access the generator terminals, speed of signal processing, and accuracy of output.so based on this we experienced the real time analysis of the stray flux to identify the power quality issues and we succeeded to put in practice.

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