International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 04, April-2015

Overview of Wavelet Transform

Detection and Analysis of Voltage sags

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Abstract— **In the recent years, power qualities issues are more important in the operation of power system equipment as well as large scale industrial applications. There are different methods to detect and analyze such PQ issues for the protection of system. This paper introduce most efficient tool of the power system i.e. Wavelet Transform for the identification and analysis of PQ issues.[2] In this paper, the impact of voltage sags at starting of larger induction motor will be detected and it is analyzed by using Wavelet Transform. This paper represents the waveform of the voltage sag events on motor and the power system which is generated by using PSCAD software and it is detected and analyzed by the Wavelet families.**

Keywords: Wavelet Transform; Fourier Transform (FT); voltage sags.

I. INTRODUCTION

The sudden change in the supply voltage and current will impact more on the healthy system. This is happened due to energizing capacitor banks, starting of large Induction Motor or any fault occurred in the power system.[1] Therefore, it is to difficult to identify the reason as well as the frequency information of the signal in conventional manner. The power quality events are classified as per the magnitude and duration of it such as voltage sags, swells, interruptions, flickering, long and short duration voltage variations. [3]

In this paper, we will concentrate on the voltage sag which is produced at the starting of larger Induction Motor [12] and line to line fault which commonly occurred in the power system. the voltage sags is defined in IEEE-1159-1995, the voltage sag is the reduction in the RMS value of the supplied voltage 0.10 per unit to .90 per unit for epoch about 0.5 cycle to 1 minute.[4] These sags are detected and classified by conventional methods such as Fourier transform Short time Fourier transform, Discrete Fourier transform, continuous wavelet transform. Here, Discrete Wavelet transform is used to analyze the varying signal due voltage sag and it will be classified from the original signal for extraction purpose, which is introduced in Induction Motor at starting as well as fault occurrence system.

The Wavelet transform is best method for capturing the voltage sags can also extract the features of the disturbances[5]The wavelet family (Db4) which is used for the resolution of time and frequency domain signal where it is varying (non stationary) signals due to any fault occurred in the system. The power quality events (such as voltage sags) are detected in PSCAD [9]at different fault condition of the 4 bus system. Then such voltage sags separated from the trapped signals by Multi- resolution analysis. The following diagram shows the faults which is occurred at the starting and faulty condition of an Induction Motor. The figure1 indicates the sag event occurred from the duration of 0.055 sec to 0.122 sec.

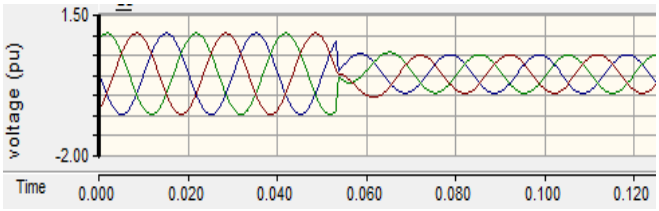

Fig.1.Fault at Induction Motor and Power System

II. CONVENTIONAL METHODS FOR ANALYSIS OF VOLTAGE SAGS

A. Fourier Transform

The Fourier Transform is an algebraic sum of sinusoidal and cosine terms of frequencies. It gives the relationship between the time domain and frequency domain of any varying signal of the power system. [2] The information of the signal will be transformed into different domain as per their time and frequencies.

The Fourier Transform is used to detect, analyse the voltage sag events occurred in the Induction motor as well as power system. It is very suitable for the analysis of stationary signals where every frequency components occurs in all time. It only provides the information of frequency content signals. It will not able to detect the voltage waveforms in time domain functions. So, Fourier Transform is used for getting the magnitude of any events which is occurred in the system.

The Fourier is represented by $X(\omega) = \int_{-\infty}^{+\infty} x(t)e^{-j\omega t}dt$ (1)

The continuous function X(ω) is the frequency domain representation of x(t) obtained by summation of an infinite number of complex exponentials. Therefore, the Fourier transform is the integration of the sine and cosine wave for the fixed time interval. But, it will not evaluate the overlapping of the signals.

The frequency information of a signal is calculated by the classical Fourier transform is an average over the entire time duration of the signal. Thus, if there is a local transient signal over small interval of time in the lifetime of the signal, the transients will contribute to Fourier transform but its location on the time axis will be lost.

B. Discrete Fourier Transform

To overcome the drawback of Fourier Transform, we use the Discrete Fourier Transform which provides the frequency contents in the steady state. It is dominant tool for the frequency analysis where the DFT fails to provides any information about the spectrum of signal [6] which changes (sudden changes) with respect of time i.e transients, flickering, swells, sags, etc. The DFT assumes the stationary but the transient signals are always non stationary. The Discrete Fourier Transform can be written as,

$$X[k] = \sum_{n=0}^{N-1} x[n]e^{\frac{-j2\pi kn}{N}} \quad (2)$$

Where $x[n]$ is a sequence obtained by sampling the continuous time signal x(t) every T_s seconds for N samples:

$$x[n] = x(nT_s) \quad n = 0,1,2,\ldots,(N-1) \quad (3)$$

The DFT also has various difficulties such as resolution in time domain, loss of signal in the sampling, lucidity of the signal.

C. Short Time Fourier Transform

The Short time Fourier transform is similar to Fourier transform except that the varying signal is multiplied by the window function w(t) with respect to time.

$$STFT(\omega,\tau) = \int_{-\infty}^{+\infty} x(t)w(t-\tau)e^{-j\omega t}dt \quad (4)$$

The STFT represents the signal in both time and frequency domain through windowing function. It has fixed window length which determines the time of occurance of the signal as well as frequency resolution.[7] But the signal is not stationary, it will be periodic or non periodic so, it cannot easily analysed by conventional transformation. So, Short time Fourier transform will be selected to extract the information from the transient signals.

The important drawback of the STFT has to considered that is it has the fixed window length it means it does not provide the good resolution in both the time and frequency which is important in illustrating the signal characteristics. For example, STFT will give good frequency resolution but poor time resolution whereas a narrow window gives good time resolution but poor frequency resolution.

III. DETECTION OF VOLTAGE SAG BY WAVELET TRANSFORM

As we have already seen, other conventional and most popular methods for the detection and analysis of the frequency and magnitude of the different kinds of the signals [11]. In that, the dB4 is mostly used for the detection of varying signals which will be introduced at the power quality events.[5] The wavelet transform performs detection and analysis of transients, non stationary signals, harmonics, voltage sags, swell etc. it overcomes the drawbacks of the Fourier Transform which will not capture the time and frequency of the signals at the sag events and also extract the features of it.[6] It is more efficient method to separate out the components which are overlapped as well as low and high frequency signals.

IV. SIMULATION AND RESULTS

In this paper, the voltage sag events are detected and analyzed by Wavelet Transform for the classification of it from the other faults or power quality issues.[8] If we taken an industrial appliances such as adjustable speed drives, induction motors, re-closers and circuit breaker etc which faces the power quality problems such as voltage sags (dips), swell and interruption, short and long duration voltage variations.[10] Here, in fig.1, we have designed slip ring Induction Motor with rated voltage 12.47 kV,1.9 MVA in PSCAD software. From this model we have detected the voltage sag events for the duration of 0.2 sec to 0.45sec. at the starting of Induction Motor with the 4-bus system. In fig.2, the voltages at the various buses are,

Ea= RMS value of Voltage at bus 1,
Eb= RMS value of Voltage at bus 2,
Ec= RMS value of Voltage at bus 3,
Ed= RMS value of Voltage at bus 4.

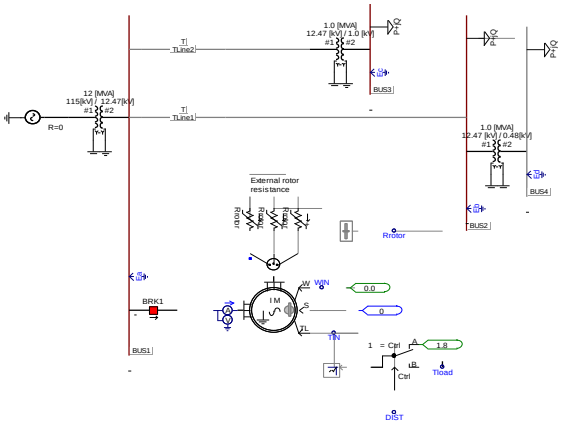

Fig.2 Design of Induction Motor for voltage sags events at strating.

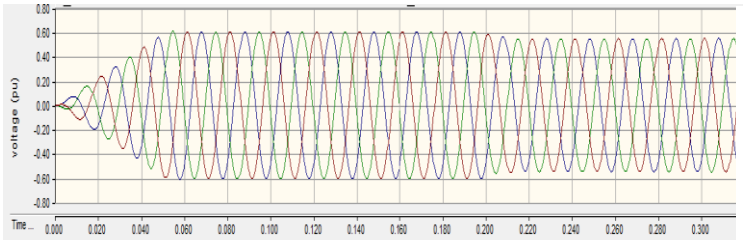

Fig. 3. Voltage sags at the starting of an Induction Motor

From Fig.3 we can easily observed magnitudes of the voltage sags at 4 bus system. The output of the PSCAD design is fed to the Wavelet Transform which will analyse the given signal or waveforms. Here, we use Wavelet family Db4 for the analysis of the voltage sags at the staring of induction motor which is very efficient methodology. Fig.4. shows the Wavelet decomposition signal up to 4-level for the analysis of voltage sags at Induction Motor. It will provide the 1600 for samples with their magnitude. This Wavelet Transform simulated in the MATLAB software where we can achieve accurate results.i.e. it gives the accurate information of signal (i.e. frequency and magnitude) [13]

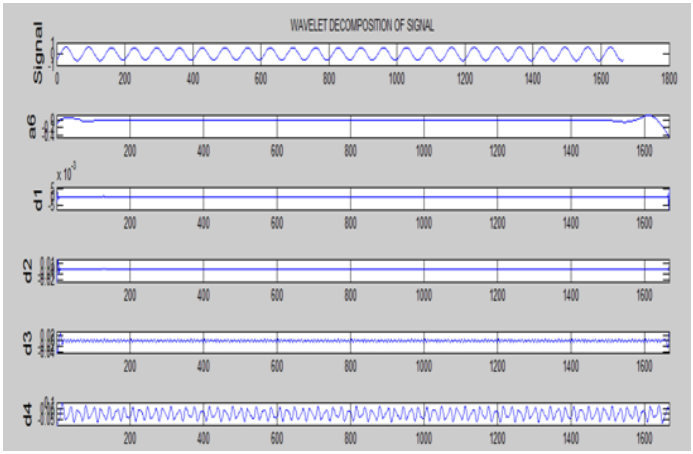

Fig.4. 4 level Wavelet Decomposition of Induction Motor at starting

Similarly, we have designed 4 bus system with Ea,Eb,Ec,Ed voltages at the different bus. This is designed in PSCAD software for the detection of voltage sags occurred at the Line to Line fault on the power system. The following fig.5 shows the PSCAD design of line to line faults which creates the sag events for the duration of 0.050 sec to 0.150 sec. It has designed with three nos. of 3- phase transformer with the rating about 1.0 MVA, Y-Y connection and 50 Hz frequency.

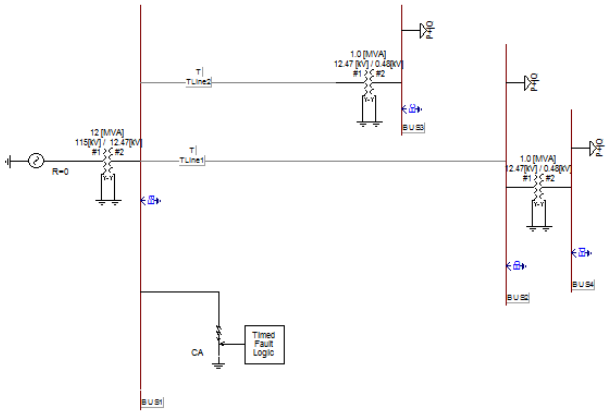

Fig.5 PSCAD Design for the Line to Line fault

This design will generate the voltage sag waveform shown in fig.6. The following indicates the magnitude and the frequency of voltage sags which is pioneered at the Line to Line fault in the one of the 4- bus system.

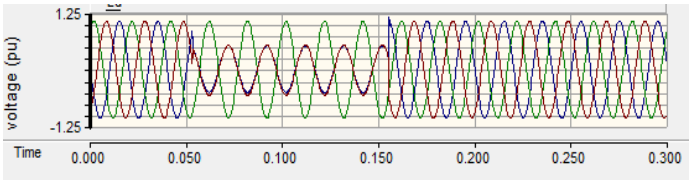

Fig.6 Voltage sags at the Line to Line fault on 4 bus system

The output of the PSCAD design of 4 bus system is fed to the wavelet decomposition for the analysis of the voltage sags. For the analysis of such voltage sag events, we have use the Wavelet Decomposition algorithm in MATLAB Software. The output of Wavelet transform shown in fig.7 indicates the 1600 samples of the voltage sags occurred on the 4 bus system.

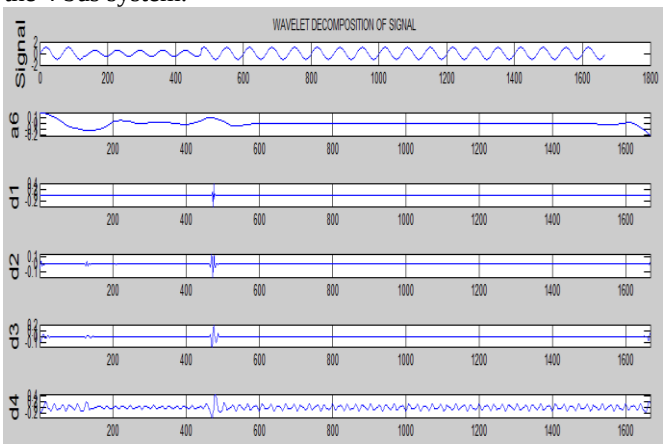

Fig.7. 4 level Wavelet Decomposition of Line to Line fault on 4 bus system

From the above studies, the Wavelet Transform is more efficient mathematical tool [2] for detection and analysis of voltage sags which will be occurred in the 3 Phase Induction Motor as well as in the power system faults.

V. CONCLUSION

From the studies, the Wavelet transform can be used for the different purposes such as detection, location and analyze the time varying signals. Due to its capability, we can apply the wavelet transform for the various power quality issues, disturbances, internal and external faults of machines, transformers and power system etc.

The Wavelet transform can be implemented where the advanced technologies are adopted. If any fault or disturbances occurred in the system then we can precisely diminish it with the help of Wavelet Transform.

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