Fault Detection and Analysis of Three Phase Induction Machine using DWT

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***Abstract*— in most of the industrial application induction machine is mostly used compared to other type of motors and so the detection of its failure is became a major and an important task to avoid the uncertain breakdown and uncertain delay in production. Here, vibration of the motor is monitored and this vibration signal having non-stationary and non-deterministic type of nature, Discrete Wavelet Transform (DWT), multi-resolution technique is used for signal processing. To achieve this target, speed of the three phase induction machine is varied using Emerson Control Techniques A.C. Drives and vibration of the motor is monitored by ADXL335 accelerometer sensor in LABVIEW software (graphical programming) and signal conditioning is performed on MATLAB software (texture programming). Finally real time online monitoring and continuous fault detection is achieved using both MATLAB and LABVIEW.**

***Index Terms*—FFT- Fast Fourier Transform, STFT- Short Time Fourier Transform, DWT- Discrete Wavelet Transform.**

I. Introduction

In most of industrial application induction machines are used to convert an electrical energy into mechanical energy. And for that low cost induction machines are used to achieve maximum profit or annual targets and these low cost motors works on their non-secure condition. So in advance failure detection in motor becomes necessary to avoid un-certain break-downs and un-certain delay in production. Here vibration monitoring is chosen for detection of fault in motor. As the faults starts arriving in motor, vibration patterns changes according to the type or nature of fault. By recognizing the pattern of vibration signal, it becomes easier to estimate the condition and reliability of that rotating equipment.

For example, faults in induction machine like loose mounting condition, load un-balance condition, phase loss condition and bearing failure condition. All these faults generates specific vibration frequency that can be detected using various signal processing techniques. Here, various signal processing techniques like: FFT-Fast Fourier Transform, STFT-Short Time Fourier Transform and DWT-Discrete Wavelet Transform are approached to make the analysis of vibration signal. Finally the best signal processing technique is selected for the further fault detection. Before making the analysis of vibration signal in any software, it is necessary to decide the platform or hardware accessories to take the vibration signal into software. Here, vibration monitoring is done using ADXL335 accelerometer-vibration sensor in LABVIEW graphical programming software. After this data acquisition, vibration signal data is imported in MATLAB texture programming software and all the signal processing techniques mentioned above are applied to make the analysis and detect the faulty frequency component in recorded vibration signal.

II. Signal Processing Techniques

A. FFT

The Fast Fourier Transform (FFT) was developed for the rapid fast calculation of the Discrete Fourier Transform (DFT) [2]. DFT as the discrete form of Continuous Fourier Transform is expressed as:

$$X[K] = \frac{1}{N}\sum_{n=0}^{N-1} x(n)e^{-jk(2\pi/N)n}$$

Where, X[K] and x(n) denote discrete frequency and time signal respectively, k and n represent the frequency and time indices, N represents the number of points that are equally spaced in the interval 0 to 2π.

B. STFT

Short Time Fourier Transform (STFT) is designed to achieve the time as well as frequency domain analysis. For that, signal is segmented into various intervals according to window size and the Fourier Transform is found for each segment. This window size is selected in such a way that signal can be considered stationary in that particular window as show in the figure 1.

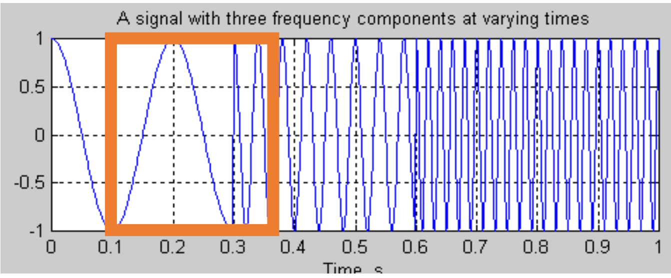

Fig.1: Window function.

So we can find the frequency details with time details of signal. STFT is calculated as:

$$STFT_f^u(t',u) = \int_t [\, f(t) \cdot W(t-t') \,] \cdot e^{-j2\pi ut} dt$$

Where, f(t) is the signal to be analysed, W is window function and t represents the time value. This equation calculates STFT window at t=t'. Here, very narrow window size will provide good time resolution and poor frequency resolution. While wide window size will provide good frequency resolution and poor time resolution. To overcome these limitations needs to go for the multi resolution technique.

C. DWT

It consist of sampling the scaling and shifted parameters. It decompose the signal into approximate and detail co-efficient which are generated by passing the signal into low pass filter and high pass filter respectively as shown in the figure 2.

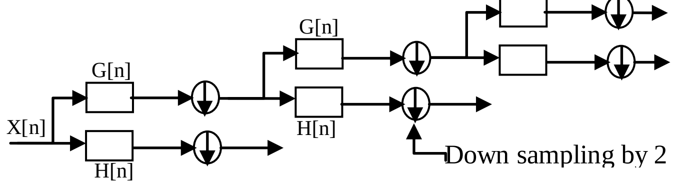

Fig2. Decomposition of discrete signal in DWT

This decomposition is expressed by an equation as:

$$X[n] = \sum_k a_{j0,k}\, \emptyset_{j0,k}[n] + \sum_{j=j_0}^{J-1} \sum_k d_{j,k}\, \Psi_{j,k}[n]$$

Where, (a) and (d) are approximate and detail coefficients respectively. $\emptyset_{j0,k}$ and $\Psi_{j,k}$ are scaling and mother wavelet functions respectively. Here, up to three level of decomposition is shown in figure 2. At each level of decomposition signal length becomes half of the original signal length, it means every time signal's half frequency components are removed and half remains. This leads to high-frequency resolution at low frequencies and high-time resolution at higher frequencies.

III. EXPERIMENT SETUP

To do vibration monitoring and fault detection, experiment setup is arranged as shown in figure 2. Here, we can see the three phase motor's speed is varied by variable speed drive and accelerometer sensor is mounted on motor's cage. Here, data acquisition card DAQ PCI-6221 is used to get the vibration data in LABVIEW software.

Fig.2: Experiment setup.

A. Load Un-balance Condition

Load un-balance condition is created by applying some pendulum type load in any one direction as shown in figure 3. The unbalance creates a vibration frequency exactly equal to the rotational speed, with amplitude proportional to the amount of unbalance. [1]

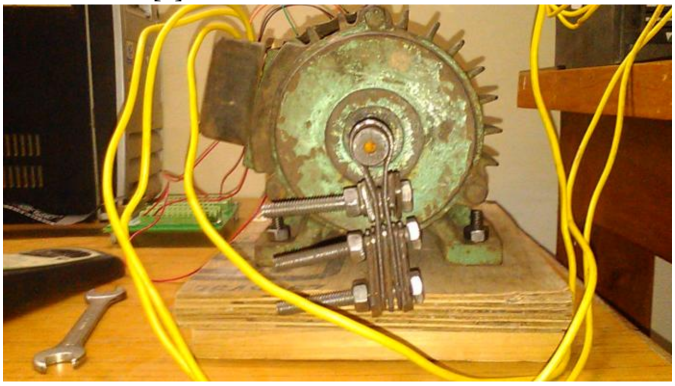

Fig.3: Load un-balance condition.

Here, motor's vibration data is recorded at 10 Hz (150 RPM) motor's running speed by NI's Data Acquisition Card PCI-6221 data analysed by MATLAB software using various signal processing techniques.

B. Loose Mounting Condition

Vibration pattern is monitored when loose mounting condition occurs. This condition is generated by loosening the mounting bolts in such a way that motor can run more freely and generates a specific vibration pattern as shown in figure 4. By experiment data it shows that motor generates multiple vibration frequencies around healthy frequency component [1].

Fig.4: Loose mounting condition.

These multiple vibration frequencies will be of random amplitude and very noisy in nature. Similar to load unbalance condition motor's vibration data is recorded at 30 Hz (900 RPM) motor's running speed using same Data Acquisition Card.

C. Phase Loss Condition

Phase loss condition is created by removing or disconnecting one of the three phases connected from Emerson Control Techniques A.C. drive (Commander SK-3400037) to three phase induction motor as shown in figure 5. It generates excessive noise and specific amount of vibration frequency.

Fig.5: Phase loss condition.

This additional frequency component will exist on each and every speed of motor. Similarly, motor's vibration data is recorded at 30 Hz (900 RPM) motor's running speed using same Data Acquisition Card.

IV. VIBRATION ANALYSIS

A. Healthy Condition

Healthy motor's vibration data is recorded at various running speed to compare with faulty frequency data. Here, at 30 Hz (900 RPM) motor's healthy condition data is shown in figure 6.

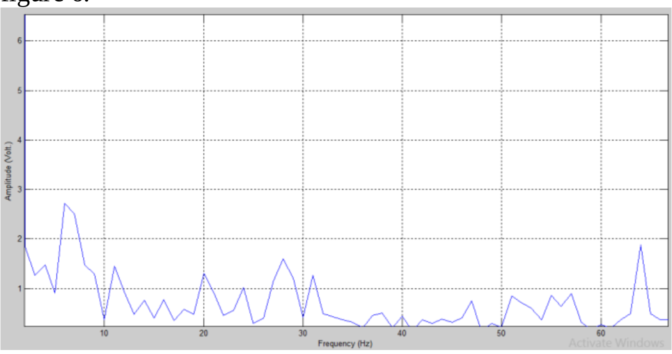

Fig.6: Healthy motor's vibration data at 30 Hz.

Here, asp per sensor's datasheet, accelerometer generates 1.5v at 0g acceleration or stable condition and its operating range is -3v to +3v d.c.

B. Load Un-balance Condition

As per experimental results, we observe that load un-balance generates the vibration frequency exactly equals to motor's running speed. These results are analyzed using FFT, STFT and DWT (up to 3 level of decomposition) techniques as shown in the following figures. These analysis is done at 10 Hz (150 RPM) motor's running speed. In FFT technique it finds the Fourier Transform of the whole signal and provides the highest frequency resolution as shown in figure 7.

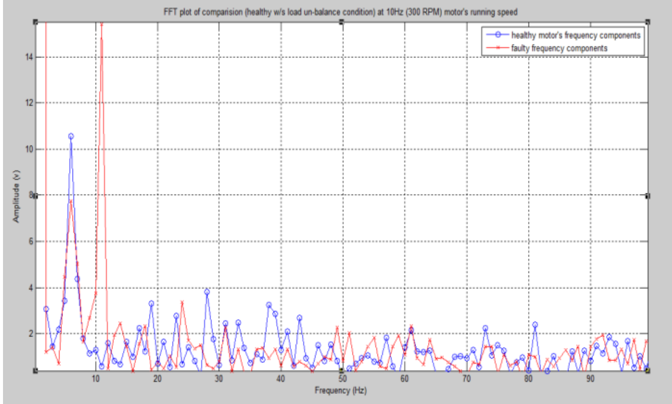

Fig.7: FFT spectrum of load un-balance condition at 10 Hz.

Using STFT technique vibration data is analyzed on various window size (111, 333 and 666 samples) at 10 Hz. From these analysis it is observed that at 666 samples window size, we achieve the optimum frequency and time resolution as shown in figure 8. While keeping 999 samples window size STFT is converted into FFT.

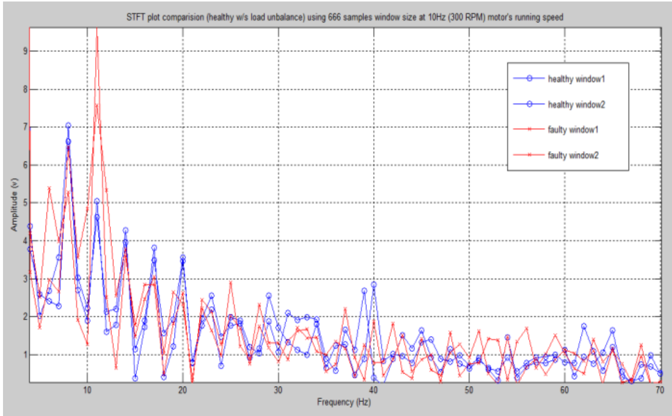

Fig.8: STFT spectrum (666 samples window) at 10 Hz.

Using DWT up to 6 level of decomposition is done using db4 mother wavelet function as shown in figure 9. From this figure we can see that up to 3 level of decomposition can provide very good frequency resolution and after third level frequency resolution reduces. So, in further fault detection up to 3 level of decomposition will be considered.

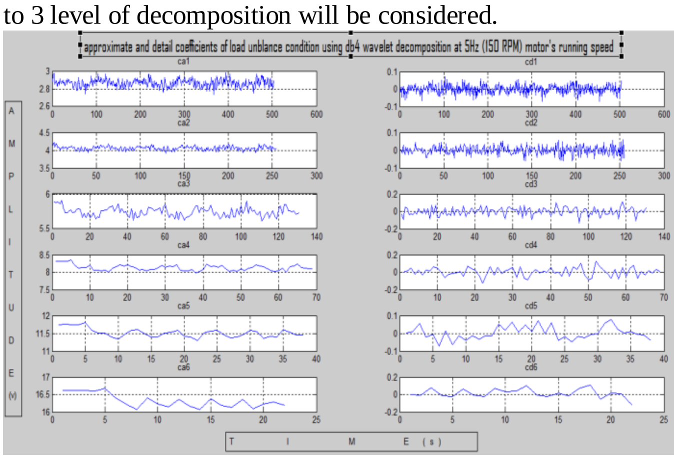

Fig.9: Wavelet decomposition up to 6 level using db4.

And also it provides very good time-frequency resolution by analysing 3rd level approximate coefficient as shown in fig.10.

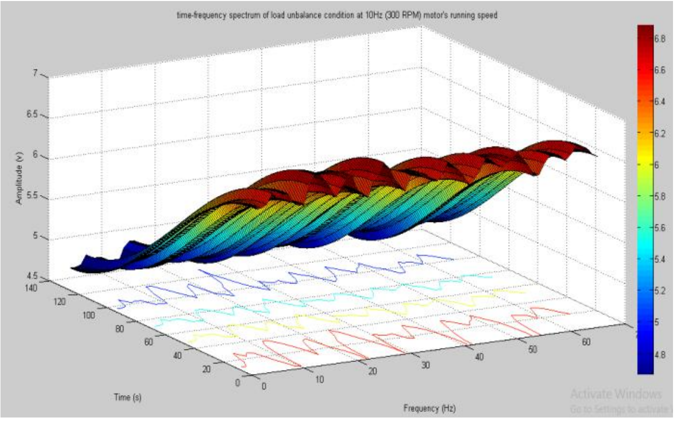

Fig.10: Time-Frequency plot of A3.

By plotting frequency spectrum of A3 coefficients we can clearly see that almost noise is removed and very good frequency resolution with fault detection is achieved as shown in figure 11. Also it is shown that at 3rd level signal length is reduced to 65 samples.

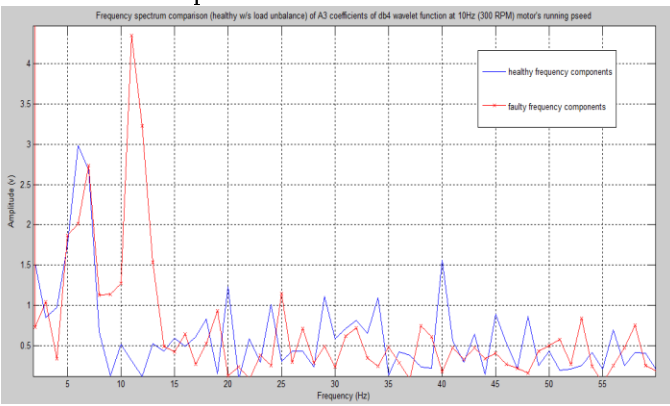

Fig.11: Frequency spectrum of A3 at 10 Hz.

C. Loose Mounting Condition

As per experimental results we can see that loose mounting will generate multiple frequencies around healthy frequency components. This analysis is done at 30 Hz (900 RPM) motor's running speed of A3 coefficients using db4 mother wavelet function in DWT as shown in figure 12. These multiple frequency component reduces gradually after healthy frequency component.

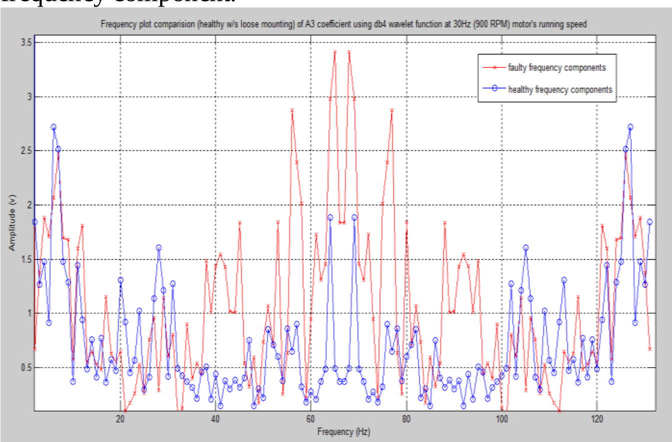

Fig.12: Frequency spectrum of A3 at 30 Hz using DWT.

These multiple frequency components are enough to consider the motor's faulty condition before any hazardous condition occurs.

D. Phase Loss Condition

In phase loss condition motor generates specific amount of vibration frequency and also very high noise. This happens because motor will try to balance the voltages between two windings rather than three. These specific amount of vibration frequency exist at each and every motor's running speed. Here, frequency spectrum of 3rd level of db4 wavelet function is shown in figure 13 and faulty frequency component is analyzed around 26 Hz.

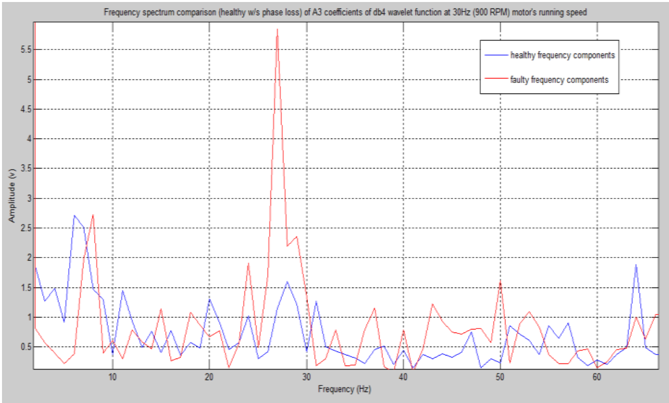

Fig.13: Frequency spectrum of A3 at 30 Hz using DWT.

V. CONCLUSION

From above analysis and experiment we can see that DWT is providing very good time-frequency resolution as well as very good noise removal from vibration signal. Hybrid programming combining LABVIEW graphical programming with MATLAB textural programming has been shown to be an effective method to build an intelligent signal monitoring and feature extraction system. Also motor's certain external faults can be easily determined by vibration analysis. In future this method can be used for bearings various fault detection and also an artificial intelligent technique (Fuzzy or Neural Network based) can be added for precisely fault classification and decision making.

VI. REFERENCES

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