BEARING FAULT DETECTION OF THREE PHASE INDUCTION MOTOR USING SOUND SIGNALS

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Abstract—Bearing faults are very common in any electric drive and it causes change in its sound. In this paper, the sound signals are recorded and analyzed for fault detection of defective balls of an induction motor bearing. Matlab software is used for sound signal analysis using Fourier and Wavelet Transform (FWT) for comparison between a healthy and a defective drive.

Keywords— Bearing Fault, Three Phase Induction Motor, Sound Signals, wavelet transform

I. INTRODUCTION

The faults of a Three Phase Induction motor (3PIM) are summarized by Chaturvedi et.al. [1-4]. These faults affect the motor performance more or less depending on severity of faults. These faults can be classified as the faults related to rotating parts, faults related to coupling between rotating part and stationary part (Bearing), faults related to stationary part and miscellaneous faults. As per the IEEE survey report the bearing faults vary from 40% to 90% depending on the machine rating; about 40% in higher capacity machines and 90% in smaller capacity machines [5-9]. Bearing faults are the major cause to make 3PIM non-operative or initiate other faults due to overheating. These faults can further divided into cyclic faults, such as ball defect or inner race or cage fault and non-cyclic faults such as outer race faults as shown in Fig. 1 [10-20]. Hence, it is necessary to continuously observe the bearing of a healthy 3PIM to reduce its downtime. In this paper, only the ball defect fault is considered just to demonstrate.

For this purpose, the sound signal is recorded using a simple mike and analyzed to detect the bearing faults of 3PIM. For analysis purpose Matlab version 12 software is used.

The paper is organized in the following way, first section gives the introduction of the bearing faults and its literature review. Next section deals with the experimental setup and data acquisition using LabView software. Third section describes the analysis using FWT of sound signal recorded during experimentation. Section four discusses the results obtained in previous section. Lastly, paper is concluded in the conclusion section.

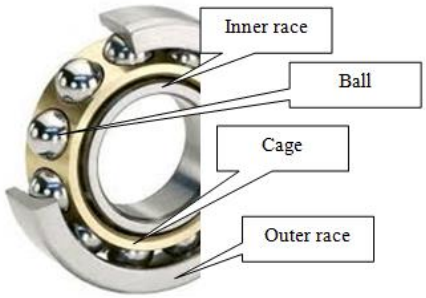


Fig-1: Different types of faults in ball bearing of 3PIM

II. EXPERIMENTATIONS

A 3PIM of 3hp rating is used for experimentation purpose as shown in Fig. 2. The specification of 3PIM is given in Table 1. The sound signal is captured using sensitive microphone.

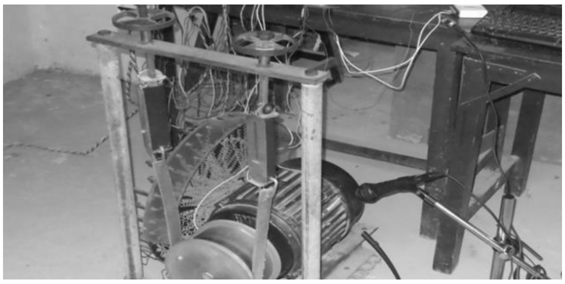


Fig-2: Experimental setup

TABLE-1: SPECIFICATIONS OF 3Φ I.M.

Type of Drive	Induction motor
Number of Phases	3
Frequency	50 Hz
Rated Voltage	415V
Rated speed	1490 rpm
Number of poles	4
Power Rating	3hp

III. FOURIER AND WAVELET TRANSFORM

Motor sound signal is recorded using micro-phone is used for analysis. The methodology proposed in this paper to detect early bearing faults by taking small window of sound signal and analyzed using FFT and wavelet transform (Haar and Db2). Matlab version 9.1 is used for analysis and the results are shown in Figs. 3-5.

Finally the authors concluded that, subtraction using DWT has shown good indication for fault. Therefore in this paper, frequency spectral subtraction using various wavelet decomposition techniques such as DWT and a comparative analysis is presented to detect bearing faults. The fault severity can also be estimated using FWT as proposed in this paper, the experimental validation is performed on the 3hp induction motor test bed.

The wavelet level at which the signal is to be decomposed is calculated by using following equation (1). [8]

$$j = int\left(\frac{Log\left(\frac{Fs}{F}\right)}{Log(2)}\right) \qquad (1)$$

The condition that is to be satisfied to use this is given in equation (9)

$$2^{-j+1}Fs = f \qquad (2)$$

Where Fs is the sampling frequency.

IV. RESULTS AND DISCUSSIONS

The Fourier transform is performed on the recorded sound signal and the Fourier coefficients are plotted on the complex plane as shown in Fig. 3 for healthy and unhealthy drive. The pattern and the range received is very different for healthy and unhealthy drive Fourier coefficients.

Similarly, the spectral density of a sound signal is computed and the Periodogram graphically shown in Fig. 4, which also clearly indicate the bearing fault of 3PIM.

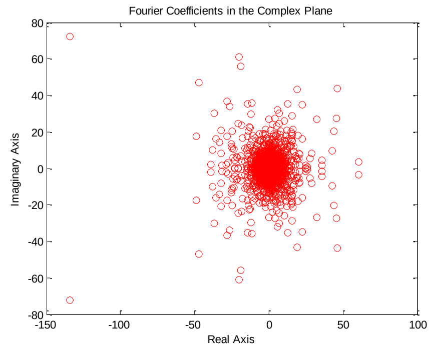
In the next part, Haar and db2 wavelet analysis is done for the recorded sound signal. The approximate and the detailed coefficients have been calculated and plotted as shown in Fig. 5. Both these coefficients are very different for healthy and unhealthy sound signals. Similarly, if the Shennon entropy is measured and compared. C. Shennon in 20th century gave a measure of spectral power distribution for a recorded signal. The power spectrum of a signal is calculated by equation (1).

$$S(m) = |X(m)|^2 \text{ ------------------------------(1)}$$

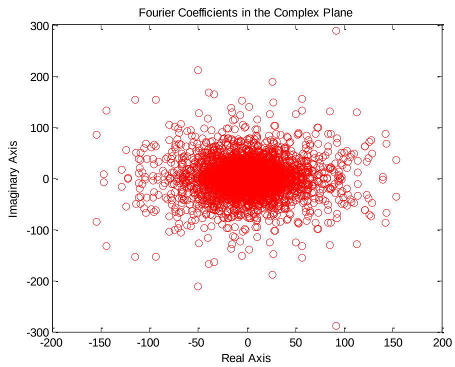
where X(m) is the discrete Fourier transform of a signal x(n).

The Shennon entropy also calculated for healthy and faulty signals and it is found that there is a clear difference in Shennon entropy which further help in identifying the faults in bearing as shown in Table 2.

The results obtained from the above analysis are validated with experimental results.

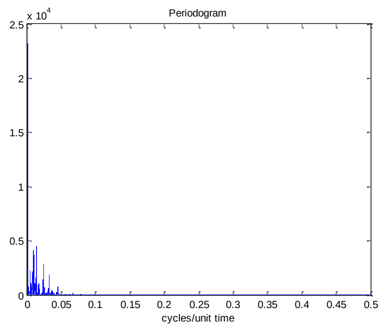


(a) Fourier coefficient in complex plane for healthy motor

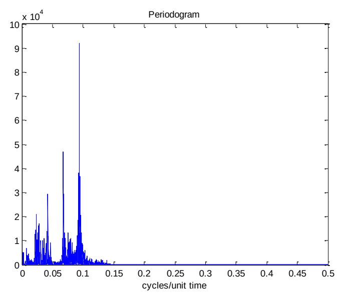


(b) Fourier coefficient in complex plane for bearing fault

Fig.3 Fourier coefficient in complex plane

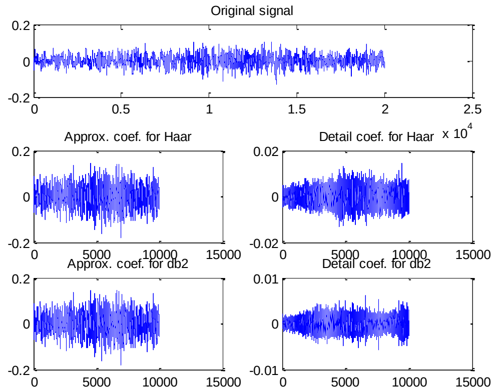


(a) Periodogram for healthy motor

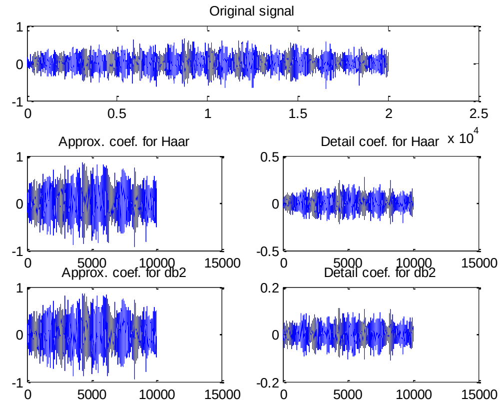


(b) Periodogram for faulty motor

Fig-4: Periodogram



(a) Healthy motor



(b) Faulty motor

Fig-5: Haar and db2 Wavelet transform of sound signal

Table–2: Shennon entropy of both healthy and faulty motor

	Healthy	Unhealthy
Shennon Entropy	57.2734	717.8802

V. CONCLUSIONS

The paper deals with the 3PIM faults specially the bearing fault identification using recorded sound signal. This signal has been analyzed by Fourier and Wavelet transforms. The Shennon energy is also one of the indicators for fault identification and tells about the severity of faults. The results clearly show that the difference between healthy and unhealthy 3PIM for coefficients of Fourier transform, spectrum density and detailed and approximate coefficient of Haar and db2 wavelet transform. The power spectral density of sound signal is also calculated in the form of Shennon entropy and found quite different for healthy and unhealthy motor.

The work may be extended for identifying other faults like faults of rotating parts and stationary parts of induction motor using sound signals.

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