A Wavelet Based Fault Detection of Induction Motor: A Review

Vinay Kumar Singh[1] Dr. S.Chatterji[2] Dr. Lini Mathew[3]
[1]M.E. Student [2]Professor and Head of Department [3]Associate Professor
[1,2,3]Department of Electrical Engineering
[1,2,3] National Institute of Technical Teachers Training and Research, Chandigarh

Abstract— This paper presents a review of the researches done on fault detection and tolerant control , main aim of the fault tolerant control and fault detection of induction motor is used the wavelet transform. Wavelet transform is much better tool for the fault diagnosis point of view and a overview of the wavelet types (continuous and discrete), machine faults detection methods and their validation. The software, generality of codes, one dimensional and two dimensional DWT and frequency characteristics components of healthy as well as faulty induction motor has explained. So Finally, stator short winding , shaft fault, bearing fault ,rotor broken bar and open winding are taken as a case study to show the better diagnosis of fault by using wavelet techniques.

Key words: Wavelet, induction motor, fault diagnosis, fast Fourier transform, fault indicator, fault tolerant

I. INTRODUCTION

Induction motor is very important in industries due to many reasons, like low maintenance simple construction, requirement, strong and high reliability like compressors, pumps and fans. Since harmonics are contained in the induction motor that may be used as fault detections in so many fields of the induction motor , it is fact that they it may operate under fault conditions these motor are really important because it is not visible. Fault can be seen when it becomes high.

There are a lot of techniques which is being used to diagnose the faults of the stator because it is noninvasive properties. There are a lot of mathematical tool used to differentiate a known continuous-time signal to different scale is called as wavelet. The wavelet transform is new technique for fault detection because of it is capable to get information in both frequency domain as well time as it provide a useful method for the fault diagnosis , if it is compared through other signal processing techniques such as Fourier transform . According to the survey of the best review has been presented for fault detection by Andrew et al. (2006). The two main method of fault diagnosis is: (1 a traditional (2 a knowledge based fault diagnosis. Fault detection techniques are combination of feature extraction tool FFT (wavelet), and the motor current signature analysis (MCSA) has been used to get the stator short circuit fault. I present era Wavelet is One of the most suitable module which is being used in both frequency as well as time domain. Wavelet is a very popular due to its multi resolution analysis and having good time localization. There are so many Signal processing techniques, such as FFT, are work on the several assumption as such as: load, constant stator fundamental frequency and motor speed which is sufficient so it does not being used for nonlinear systems.

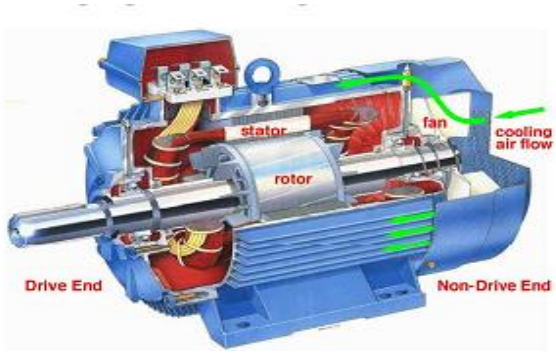

Fig. 1.1: Cut View of Induction Motor

II. LICTURE SEARCH

A. Air Gap Eccentricity

Air gap eccentricity is mundane rotor fault of induction machines. This fault engenders the quandaries of vibration and noise. In a salubrious machine, the rotor is center-aligned with the stator bore, and the rotor's center of rotation is identically tantamount to the geometric center of the stator bore. When the rotor is not center aligned, the unbalanced radial forces unbalanced magnetic pull (UMP) can cause a stator-to-rotor rub, which can result in damage to the stator and the rotor [25, 27]. There are three types of air gap eccentricity [2, 3]:

(1) Static eccentricity
(2) Dynamic eccentricity
(3) Commixed eccentricity

Static eccentricity is a steady pull in one direction which engenders UMP. It is arduous to detect unless special equipment used [2].A dynamic eccentricity on the other hand engenders a UMP that rotates at the rotational speed of the motor and acts directly on the rotor. This makes the UMP in a dynamic eccentricity more facile to detect by vibration or current monitoring. Actually, static and dynamic eccentricities incline to coexist. Ideal centric conditions can never be postulated. Therefore, an intrinsical grade of eccentricity is implicatively insinuated for any authentic machine. The cumulated static and dynamic eccentricity is called commixed eccentricity as shown in fig 1.3.

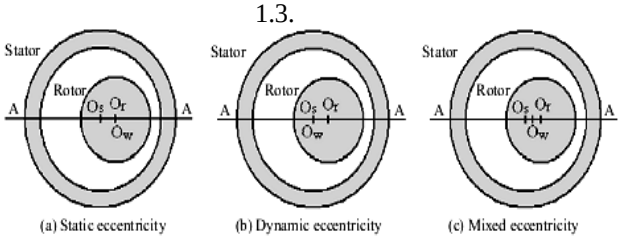

Fig. 1.3: Diagram of Eccentricity Fault

B. Bearing Faults

Bearings are prevalent elements of electrical machine. They are employed to sanction rotary kineticism of the shafts. In

All rights reserved by www.ijsrd.com

fact, bearings are single most astronomically immense cause of machine failures. According to some statistical data, bearing fault account for over 41% of all motor failures[12].A fault in bearing could be imagined as a minute aperture, a pit or a missing piece of material on the corresponding elements. Under mundane operating conditions of balanced load and a good alignment, fatigue failure commences with diminutive fissures, located between the surface of the raceway and rolling elements, which gradually propagate to the surface engendering detectable vibrations and incrementing noise levels . Perpetuated stress causes fragments of the material to break loose, engendering localized fatigue phenomena kenned as flaking [10].

[9]. Misalignment of the bearing is additionally a mundane result of defective bearing installation. Regardless of the failure mechanism, defective rolling element bearings engender mechanical vibrations at the rotational speeds of each component. Imagine for an aperture on the outer raceway: as rolling elements move over the defect, they are customarily in contact with the aperture which engenders an effect on the machine at a given frequency. Thus, these characteristic frequencies are cognate to the raceways and the balls or rollers, can be calculated from the bearing dimensions and the rotational speed of the machine.

Bearing consists of two rings called the inner and the outer rings. A set of balls or rolling elements placed in raceways rotate inside these rings as shown in fig 1.4. A perpetuated stress on the bearings causes fatigue failures, customarily at the inner or outer races of the bearings. Minuscule pieces break loose from the bearing, called flaking or spalling. These failures result in rough running of the bearings that engenders detectable vibrations and incremented noise levels. This process is availed by other external sources, including contamination, corrosion, incongruous lubrication, infelicitous installation, and brine ling. The shaft voltages and currents are withal sources for bearing failures. These shaft voltages and currents result from flux perturbance such as rotor eccentricities



Fig. 1.4: Bearings of Induction Motor

Bearing consists of two rings called the inner and the outer rings. A set of balls or rolling elements placed in raceways rotate inside these rings as shown in fig 1.4. A perpetuated stress on the bearings causes fatigue failures, customarily at the inner or outer races of the bearings. Small pieces break loose from the bearing, called flaking or spalling. These failures result in rough running of the bearings that engenders detectable vibrations and incremented noise levels. This process is availed by other external sources, including contamination, corrosion, incongruous lubrication, incongruous installation, and brine ling. The shaft voltages and currents are additionally sources for bearing failures. These shaft voltages and currents result from flux perturbance such as rotor eccentricities [4].

C. Broken Rotor Bar

Induction motor rotors are of two types: cast and fabricated. Previously, cast rotors were only utilized in minuscule motors. However, with the advent of cast ducted rotors, casting technology can be used even for the rotors of motors in the range of 3000 kW. Cast rotors can virtually never be rehabilitated once faults such as broken rotor bars develop in them. Fabricated rotors are generally found in more immensely colossal or special application motors. A cast rotor of induction motor is shown in fig.1.5



Fig. 1.5: Cast Rotor of Induction Motor

A broken rotor bar produces a backward rotating field because of the rotor asymmetry. A broken rotor bar leads to an enhanced field around the fault because of the lack of local demagnetizing slip frequency induced current in these rotor slots. The flux density becomes progressively higher in magnitude close to the fault. The results show that, in case of one broken bar, the degradation in the steady state torque performance is in the order of 2-4%, whereas for three and five broken bars it is between 10-15%, for a motor with 40 rotor bars [10]Environmental stresses caused by for example contamination and abrasion of rotor material duo to chemicals or moisture Mechanical stresses due to lose laminations, fatigued parts and bearing failure

D. Shaft Fault

The rolling element shaft is one of the most critical components in rotating electrical machinery due to the fact that the immensely colossal majority of quandaries arise from faulty shaft .A anterior report [1] on failed components of induction motors has pointed out that the most consequential contributor to bearing failure is inadequate maintenance, and this can, in turn, result in winding failure within the machine. Therefore, opportune monitoring of shaft condition is highly cost efficacious in reducing capital loss. Vibration-predicated monitoring techniques, both in the time and frequency domains, have been widely utilized for detection and diagnosis of shaft defects for several decades.

A brief review of vibration monitoring techniques can be found. These methods have traditionally been applied, discretely, in the time and frequency domains. A time-domain analysis focuses principally on statistical characteristics of the vibration signal such as peak level, standard deviation, skew ness, and kurtosis and crest factor. A frequency domain approach uses Fourier methods to transform the time-domain signal to the frequency-domain where further analysis is carried out, conventionally

All rights reserved by www.ijsrd.com

utilizing vibration amplitude and power spectra. It should be noted that utilization of either domain .

E. Bearing in Machine

Motor systems are very consequential in modern society. They convert virtually 60% of the electricity engendered throughout the world into other forms of energy to provide power to 57

Other equipment. In the performance of all motor systems, bearings play a paramount role. Many quandaries arising in motor operations are linked to bearing faults. Thus fault diagnosis or condition monitoring of a motor system is inseparably cognate to the diagnosis of the bearing assembly. Due to the close relationship between motor system development and bearing assembly performance, it is arduous to imagine the progress of modern rotating machinery without consideration of the wide application of bearings. In additament, the faults arising in motors are often linked with bearing faults around (40%) , Moreover, according to an IEEE motor reliability study, bearing faults have been shown to be the most frequent faults in induction machines (41%) followed by stator (37%) and rotor faults (10%). In many instances, the precision of the instruments and contrivances used to monitor and control the motor system is highly dependent on the dynamic performance of bearings. Bearing vibration can engender noise and degrade the quality of a product line which is driven by a motor system. Heavy bearing vibration can even cause the entire motor system to function incorrectly, resulting in downtime for the system and economic loss to the customer. Opportune monitoring of bearing vibration levels in a motor system is highly cost efficacious in minimizing maintenance downtime- 2.5 Bearing fault

The fault is postulated to be modelled as a minute aperture engendered from a missing piece of material on the corresponding element. Bearing defects may be categorized as distributed or local. Distributed defects include surface roughness, waviness, and vibration analysis is a conventional method for bearing fault detection.58Local or wear defects cause periodic impulses in the vibration signals. Amplitude and period of these impulses are resolute by shaft rotational speed, fault location and bearing dimensions. A very consequential aspect of condition monitoring of induction motor is to detect the mechanical faults. The reliability of an induction motor is of paramount consequentiality in industrial, commercial, aerospace and military applications. Bearing play a paramount role in the reliability and performance of all motor systems. Due to close relationship between motor system development and bearing assembly performance, it is arduous to imagine the progress of modern rotating machinery without consideration of the wide application of bearing advisement; most faults arising in motors are often linked to bearing faults. The result of many studies show that bearing quandaries account for over 40% of all machine failure [12]. In present chapter, investigations have been done to find the application of advanced signal processing techniques for detection of bearing faults.

F. Types of bearing faults

Monitoring of bearing faults in induction motor using vibration and Bearing fault can be detected by analysing the vibrations in the high frequency spectra. Each type of bearing faults corresponds to a certain vibration frequency. The ball bearing defects can be categorized as outer race defect, inner race defect, ball defect and train defect and the frequencies to detect these faults are given by

The different faults occurring in a rolling element bearing can be classified according to the damaged element are as follows and ball bearing detail also shown in figure 5.1

- Inner raceway
- Outer raceway

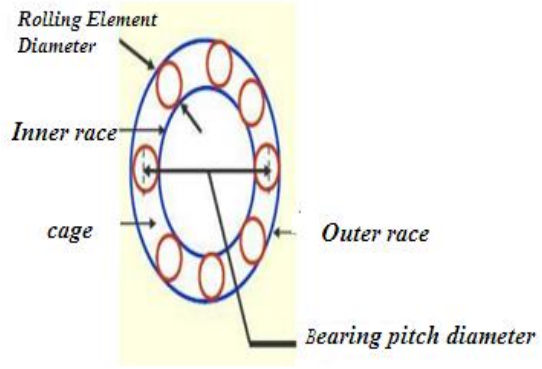

Fig. 5.1: Ball bearing details

1) Inner race defect or Ball pass Inner raceway frequency

It indicates the rate at which the ball passes a point on the track of the inner raceway. The value of the f_{BPFI} is equal to the No. of bearing ball and multiplied by the difference between shaft rotational frequency F and fundamental cage frequency Fc.

$$f_{BPFI} = \frac{n}{2}\frac{N}{60}(1+\frac{d}{D}\cos\beta) \quad \text{.....5.1}$$

Where:

n = Number of balls

N = rotational speed in RPM

d = Ball diameter

D = Bearing pitch diameter

β = Ball contact angle with the race

G. Outer race defect or Ball pass outer raceway frequency

Similarly to the ball pass inner raceway frequency F_{bpi} , the F_{bpo} is defined as the rate at which the ball pass a point on the track of the outer raceway, value of F_{bpo} is the function of the number of bearing balls n and the difference between the outer raceway frequency F_o and the fundamental cage frequency F_c.

$$f_{BPFO} = \frac{n}{2}\frac{N}{60}(1-\frac{d}{D}\cos\beta) \quad \text{.....5.2}$$

Where:

n = Number of balls

N = rotational speed in RPM

d = Ball diameter

D = Bearing pitch diameter

β = Ball contact angle with the race

All rights reserved by www.ijsrd.com

H. Summary

The most frequent faults in the bearing of induction motor are explicated in details in this

Chapter. The overview of variants of vibration is presented since vibration is one of the parameter that is associated with the bearing fault. This chapter contains all the details associated with the bearing faults and the characteristic frequency associated with each bearing fault. In additament to above all some vibration factor analysis parameters are additionally discussed in this paper.

III. Different Signal Processing Technique For Fault Detection

A. Fast Fourier Transform (Fft)

Although the Discrete Fourier Transform (DFT) is the most straight mathematical procedure for determining frequency content of a time domain sequence, it's terribly inefficient. As the number of points in the DFT is incremented to hundreds, or thousands, the amount of compulsory number crunching becomes extortionate.

In 1965 a paper was published by Cooley and Tukey describing a very efficient algorithm to implement DFT. That modified algorithm is now kenned as the Fast Fourier Transform [10]. FFT is simply a computationally efficient way to calculate the DFT. By making use of periodicities in the sine that are multiple to do the transforms, the FFT greatly reduce the amount of calculation required. Functionally, the FFT decomposed the set of date to be transformed into a series of more diminutive data sets to be transformed. Then, it composes those more minuscule sets into even more minute sets. At each stage of processing, the results of the precedent stage are cumulated in special way. Finally, it calculates the DFT of each minuscule data set. [1]

FFT algorithm can be used to detect the various types of motor fault. The Power spectrum is computed from the basic FFT function. The power spectrum shows power as the mean squared amplitude at each frequency line. The FFT in Lab VIEW and Lab Windows returns a two-sided spectrum in complex form (real and imaginary parts), which must scale and convert to polar form to obtain magnitude and phase. The frequency axis is identical to that of the two-sided power spectrum.

B. Short time Fourier transform (stft)

The short time Fourier Transform is the most widely used method for studying non-stationary signals. The rudimentary conception of the short time Fourier transform is to break up the initial signal into minuscule time segments and apply the Fourier transform to each time segment to ascertain the frequencies that subsisted in that segment. The totality of such spectra denotes that the spectrum is varying in time. The circumscription of the short time Fourier transform lies in the infeasibility to achieve finer and finer time localization by utilizing more minute window functions. As the time becomes more diminutive, the information content of the resulting spectrum decreases.

C. Wavelet Transform (Wt)

Wavelets are functions that can be habituated to decompose signals, homogeneous to how to utilize involute sinusoids in the Fourier transform to decompose signals. The wavelet transform computes the inner products of the analyzed signal and a family of wavelets. In contrast with sinusoids, wavelets are localized in both the time and frequency domains, so wavelet signal processing is felicitous for those signals, whose spectral content changes over time [2].

$$\Psi_{\alpha,\beta}(t) = \frac{1}{\alpha}\Psi t\left(\frac{t-\beta}{\alpha}\right) \quad (1.1)$$

Suppose that all signals x(t) satisfy the condition

$$\int_{-\infty}^{\infty}|x(t)|2DT < \infty \quad (1.2)$$

Which implies that x(t) decays to zero.

The wavelet transform, CWT of (α, β) of a time signal x(t) can be defined as

$$cwt(\alpha,\beta) = \frac{1}{\sqrt{\alpha}}\int_{-\infty}^{\infty} x(t)\,\Psi*\left(\frac{t-\beta}{\alpha}\right)DT \quad (1.3)$$

Where, Ψ(t) is an analyzing wavelet and Ψ*(t) is complex conjugate of Ψ(t)

D. Discrete Wavelet Transform (Dwt)

Unlike the discrete Fourier transform, which is a discrete version of the Fourier transform, the DWT is not really a discrete version of the continuous wavelet transform. To implement the DWT, discrete filter banks are used to compute discrete wavelet coefficients. Two-channel perfect reconstruction (PR) filter banks are a common and efficient way to implement the DWT [29]. The signal Signals usually contain both low-frequency components and high-frequency components. Low-frequency components vary slowly with time and require fine frequency resolution but coarse time resolution. High frequency components vary quickly with time and require fine time resolution but coarse frequency resolution. Multi-resolution analysis (MRA) method is used to analyze a signal that contains both low and high frequency components. The DWT is well-suited for multi-resolution analysis. The DWT decomposes high-frequency components of a signal with fine time resolution but coarse frequency resolution and decomposes low-frequency components with fine frequency resolution but coarse time resolution. DWT-based multi-resolution analysis helps us better understand a signal and is useful in feature extraction applications, such as fault detection, peak detection and edge detection.

IV. Conclusion

- This review is carried out on two paramount issues. First, is the fault tolerant control and second, is the wavelet in the induction motors fault diagnosis. There are many conclusions that can be drawn from this review:
- The erudition about the induction motor frequency characteristics is very paramount in either the faulty or salubrious case.
- The wavelet is considered as a potent implement in the fault detection and diagnosis of induction motors.
- The amendment of fault detection and diagnosis can be exploited by the wavelet properties to get high detection and diagnostics efficacy.
- Theories of wavelet need to be pushed forward to ascertain the best cull of mother wavelet.
- The wavelet transform can be used to detect and identify the inverter faults.

All rights reserved by www.ijsrd.com

– The wavelet can distinguish correctly the faults and thermal effects that make the parameters such as resistance and inductance vary. Conclusively, the wavelet can be utilized with any technique of the machine drive and control.

ACKNOWLEDGEMENT

I am extremely grateful to Mrs.Dr. Lini Mathew, Associate Professor at NITTTR Chandigarh, for giving me invaluable guidance in the area of Health monitoring of an Induction Motor and offering me the opportunity to hold out this study further. It was the essential encouragement that enables me to pursue my work in this area.

REFERENCES

[1] M. E. H. Benbouzid, H. Nejjari, R. Beguenane, and M. Vieira, "Induction motor Symmetrical Faults Detection using Advanced Signal Processing Techniques," IEEE Transactions on Energy Conversion, Vol. 14, No. 2, pp.147-152, June 1999.
[2] W. T. Thomson, D. Rankin, and D. G. Dorrell, "On-line Current Monitoring to Diagnose Air-gap Eccentricity in Large Three-Phase Induction Motors-Industrial Case Histories verify the Predictions," IEEE Transactions on Energy Conversion, Vol. 14, No. 4, pp1372-1378, Dec 1999.
[3] Faiz, J., Ebrahimi, B.M., Akin, B., Toliyat H.A., "Dynamic Analysis of Mixed Eccentricity Signatures at various Operating Points and Scrutiny of related indices for Induction Motors", Electric Power Applications, IET, Vol.4 , No.1, pp. 1 – 16, 2010.
[4] RincyRaphael , Bipin PR "Fault Detection of Induction Motor using Envelope Analysis" International Journal of Advancements in Research & Technology, Volume 2, Issue 7, July -2013
[5] E.Anbarasu,M.Karthikeyan "Modelling Of Induction Motor and Fault Analysis'' International Journal of Engineering Science and Innovative Technology (IJESIT) Volume 2, Issue 4, July 2013
[6] Alberto Bellini, FiorenzoFilippetti, Giovanni Franceschini, and Carla Tassoni, "Closed-Loop Control Impact on theDiagnosis of Induction Motors Faults", IEEE Transactions on Industry Applications, Vol. 36, No. 5, pp. 1318-1329, 2000.
[7] Joksimovic, G. M., and Penman, J., "The Detection of Inter-turn Short Circuits in the Stator Winding of Operating Motors", IEEE Transactions on Industrial Electronics, Vol.47, No. 5, October, pp. 1078-1084, 2000.
[8] M. Haji and H. A. Toliyat, "Pattern Recognition – A Technique for Induction Machines Rotor Broken Bar Detection," IEEE Transactions on Energy Conversion, Vol. 16, No. 4, pp. 312–317, 2001.
[9] Arkan M., Perovic D. K. and UnsworthP.,"Online Stator Fault Diagnosis in Induction Motors", IEEE Proceedings Electric Power Applications,Vol. 148, No. 6, November, pp. 537-547, 2001.
[10] R. M. Tallam, T. G. Habetler, and Ronald G. Harley, "Stator Winding Turn-fault Detection for Closed-Loop Induction Motor Drives," IEEE Industry Applications Society Annual Meeting, pp1553-1557, 2002.

All rights reserved by *www.ijsrd.com*