International Journal of Applied Electrical and Electronics Engineering
Volume1, Issue 3, 2025

An Overview of Induction Motor Fault Diagnostic and Monitoring Techniques

Anteneh, Thomas, Department of Electrical Engineering,Ethiopia

Research Article

Date of Submission: 20-04-2025 Date of Acceptance: 15-05-2025 Date of Publication: 19-06-2025

Abstract

Transportation, mining, petrochemical, manufacturing, and almost every other industry using electricity utilize induction motors extensively. These motors provide a very high level of dependability since they are straightforward, effective, strong, and durable. However, just like any other machine, they are susceptible to malfunctions that, if ignored, might eventually cause the system to collapse catastrophically. Fault detection has made extensive use of online condition monitoring of induction motors. In order to identify future research opportunities, this article explores the many types of faults and studies both traditional and novel methods for induction motor problems.

Keywords

Fast Fourier Transforms, Fuzzy Logic, Artificial Neural Networks, Computer Simulation, Data Acquisition, Induction Motors, Parameter Estimation, Vibration Measurement, and Wavelet Transforms

Introduction

Every industry relies heavily on induction motors. However, heavy-duty cycles, unfavorable operating conditions, installation and manufacturing issues, etc., will ultimately lead them to fail, just like any other machine. The area of problem diagnostics in induction motors is becoming more significant due to the growing demands for efficiency and dependability. Failure to anticipate the issues might lead to significant income losses and jeopardize operational safety and dependability. Nonetheless, a variety of techniques have been put forward for defect diagnosis and detection; however, the majority of these techniques need a high level of skill to implement effectively. To allow even inexperienced operators with little system understanding to scan the problem situation and make trustworthy judgments, simpler methods are required.

Primary faults and associated secondary faults may affect an induction motor. The origins of induction motor defects are categorized in Fig. 1 (a). The internal fault tree for an induction motor is shown in Fig. 1(b), whereas the external fault tree is shown in Fig. 1(c).

In general, an induction motor may experience an external or internal problem. A defect might have an electrical or mechanical cause. Depending on where the problem is located, it might be categorized as either a rotor or stator defect. defects related to the moving components, such as bearings

and rotor defects include cooling issues [1]. In particular, bearing failures, stator faults, rotor faults, air gap eccentricity, mechanical vibrations, etc. may all be roughly categorized as

induction motor problems. The relative likelihood of different faults occurring in an induction machine is shown in Fig. 2 [2].

This study offers a thorough examination of techniques for identifying problems with induction motors and suggests topics for further investigation. Predicting early machine defects requires the use of systematic methodologies.

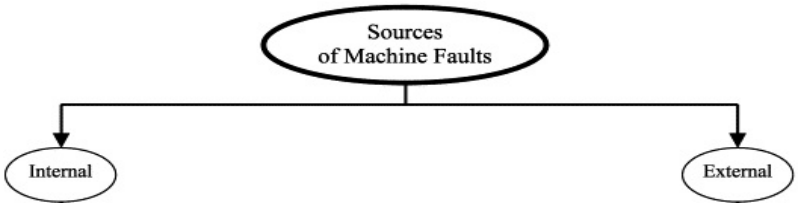


Fig.1(a) Sources of Machine Faults

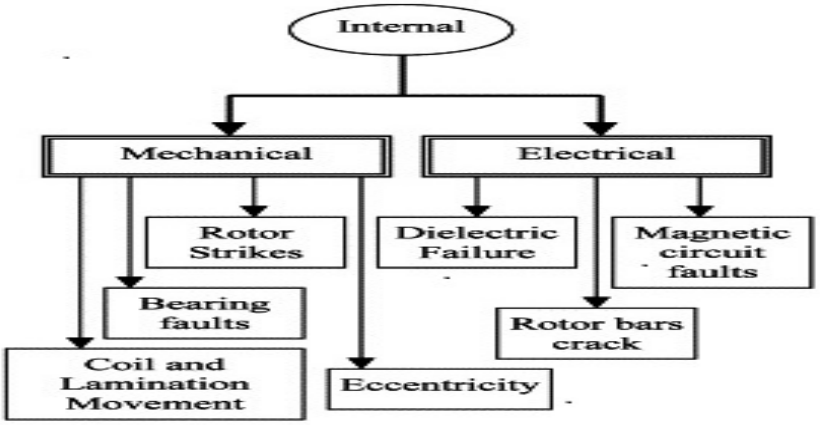


Fig. 1(b) Block Diagram Presentation of Internal Faults

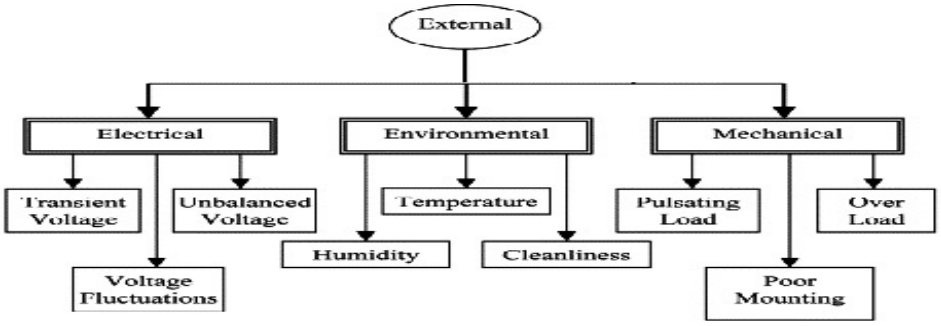


Fig. 1(c) Block Diagram Representation of External Faults

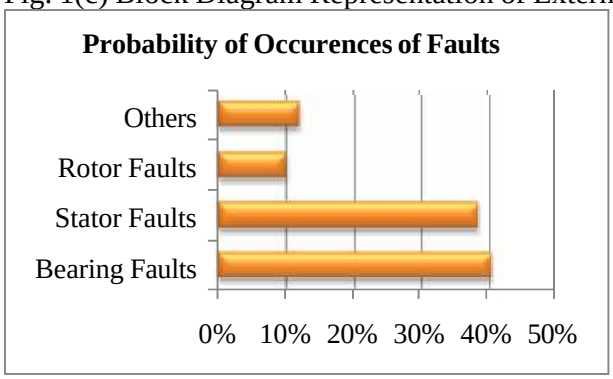


Fig.2. Faults by % in an Induction Motor

A typical diagnostic system [3], seen in Fig. 3, comprises of a sensor assembly that delivers the problem signal to a signal processing unit. The signal processing unit then transmits the result to expert systems for analysis, finally detecting the related defect.

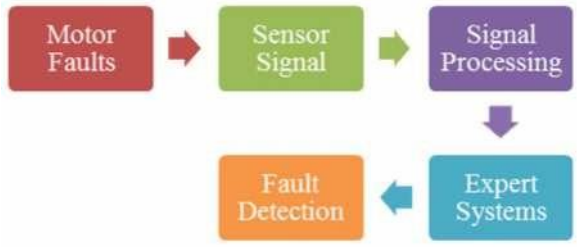


Fig. 3. On-Line Fault Monitoring of Induction Motor

Investigating the accompanying abnormalities in machine current, voltage, and leakage flux is typically how condition monitoring and fault diagnostics are accomplished. Other techniques [4-5] that have been reported to identify fault situations including insulation faults [6], partial discharge [7], and lubrication fluid and bearing deterioration [8] include

monitoring the core temperature, bearing vibration level, and pyrolyzed products.

Fast Fourier Transform Spectral Signature analysis [9–11], vibration analysis [12–13], temperature measurements [14–16], harmonic analysis of speed fluctuations [17–19], state or parameter estimation [20–22], axial flux or air gap torque analysis [23–25], acoustic noise arrangement [26–27], magnetic field analysis [28–30], fuzzy logic and neural networks [31–33], etc.

Induction Motor Faults

Induction motor failure diagnostics has received significant attention. Induction motor problems are primarily classified into the following five types based on the area in which they occur.

Bearing Faults

A rolling-element bearing typically consists of two concentric rings. Between the inner and outer rings, a group of balls or rollers rotate in raceways. There are two types of bearing faults [34]: "distributed" and "local." Misaligned races, waviness, surface roughness, and off-size rolling elements are examples of distributed flaws. Spalls, pits, and fissures are examples of localized flaws.

on the surfaces that roll. The location, speed, and bearing size of the anomaly determine the period and amplitude of the impact vibrations that these localized flaws produce when a rolling roller passes over their surface. The defective bearings cause mechanical vibrations. These vibrations occur at each component's rotating speed. The characteristic frequencies linked to the raceways and the balls or rollers are determined by the machine's rotational speed and bearing diameters. By looking at these frequencies, the bearing's condition may be determined. Mechanical vibration analysis methods are used to do this job.

Stator Faults

Thermal, electrical, mechanical, and environmental stressors may all affect an induction motor [35–37]. Such demanding operating conditions are responsible for the majority of stator problems. Among the most common and possibly harmful errors in the stator winding are turn-to-turn, coil-to-coil, open circuit, phase-to-phase, and coil-to-ground [38]. If ignored, they might ultimately lead to the motor's catastrophic breakdown. The following are the three primary categories of stator defects covered in [39].

a) Frame:

Vibration
Circulating currents
Earth's flaws
Coolant loss

b) Lamination

Slackening of the core
The core hot spot

c) Faults in stator windings:

Turn-to-turn faults, fretting of insulation, local damage to insulation, damage to connections, discharge erosion of insulation, conductor displacement, contamination of insulation by moisture, oil, or dirt, cracking of insulation, and so on are examples of end winding portions. Slot part (conductor displacement, insulation fretting).

Rotor Faults

Mechanical issues like rotor eccentricity or electrical failures like bar defects or bar breakage may cause rotor faults [40]. Thermal strains, hot spots, or fatigue stresses during brief operations like start-up—particularly in big motors—cause the initial defect. A broken bar drastically alters torque, endangering the reliable and safe functioning of electric machinery [41]. Air gap eccentricity is associated with the second kind of rotor defect. This defect is often caused by a variety of technical issues with induction motors, including shaft misalignment and load imbalance. Long-term load imbalance may affect air gap symmetry and harm the bearings and bearing housing. Horizontal, vertical, or radial misalignment between a shaft and its linked load is referred to as shaft misalignment. A steady radial force caused by shaft misalignment will cause the rotor to move from its usual position.Eccentricity Faults

An induction motor's eccentricity is caused by an uneven air gap between the stator and rotor [42]. Static and dynamic air-gap eccentricity are the two main forms of air-gap eccentricity. There have also been accounts of the axial nonuniformity of the air gap, known as inclined eccentricity [44], and a combination of both kinds, known as mixed eccentricity [43]. For static air-gap eccentricity, the minimum radial air-gap length is set in space. Conversely, with dynamic eccentricity, the center of rotation and the center of rotor do not line up. In this instance, the minimal air gap location rotates with the rotor rather than being fixed in space. Static eccentricity may result from improper rotor or stator placement during the commissioning stage. The ovality of the stator core might possibly be the reason. A bent shaft, bearing wear and movement, or mechanical resonances at key speeds may all contribute to dynamic eccentricity.

Vibration Faults

Induction motors naturally experience vibrations, which are brought on by the motors' mechanical components oscillating. The external system that is connected to the machine shaft reflects these oscillations. As a result, a machine-related frequency spectrum that is exclusive to a healthy motor is produced. Every motor malfunction modifies the spectrum's frequency component. To identify and diagnose faults, this may be compared with the reference spectrum.

Fault Diagnosis

An induction motor's supply current spectrum may be examined to identify any issues that

may arise. Only the forward spinning magnetic field will revolve at synchronous speed in a healthy motor; the backward rotating field will not exist. Any failure will produce in a backward spinning field in the air gap, which will alter the stator current spectrum. Table 1 summarizes the different frequency components that were added to the supply current spectrum as a result of failures [45]. The associated motor problems may be identified by keeping an eye on the different frequencies listed in Table 1. However, it has been noted [46–47] that these frequency components cannot be regarded as precise indicators of the occurrence of motor faults because they can be found in the spectrum of even healthy motors due to inevitable manufacturing symmetries, misalignment, etc. Over the years, numerous methods [48–49] have been proposed and developed that offer a good measure of the occurrence of faults in induction motors.

Table 1. Frequency Components of Induction Motor Faults

Faults	**Frequency**
Bearing Fault	$f_{cbf} = f_s \pm nf_{rc}$ $f_{rc} = \frac{N_b f_s}{2}\left[1 - \frac{D_b}{D}\cos\beta\right]$
Rotor Fault	$f_{cbrf} = f_s \pm n\frac{(1-s)}{P}f_s$
Eccentricity	$f_{ce} = f_s \pm nR_s \pm O_{re}\frac{(1-s)}{P} \pm O_{smh}$

where,

f_{cbf} = components generated by bearing faults f_s = supply frequency
n = 1,2,3… [Integral values]
f_{rc} = characteristics race frequencies N_b = number of bearing balls
D_b = ball diameter
D_p = bearing pitch diameter
= contact angle of the ball on the races
f_{cbrf} = components generated by broken rotor faults P = number of pole-pairs
s = per-unit slip
f_{ce} = components associated with eccentricity O_{re} = rotating eccentricity order
O_{smh} = stator MMF harmonic order R_s = number of rotor slots

Detection of Bearing Faults

Vibration Spectrum Analysis

High frequency components of vibration are produced by the forces acting on the rolling element bearing in electrical machines. These high frequency components are mostly caused by friction under normal circumstances, but in the event of a bearing malfunction, shock pulses may also be detected as a result of lubricating layer cracks between the friction surfaces. This technique uses a piezoelectric accelerometer to analyze the vibration spectrum of an induction machine by extracting the frequency domain representation from a time domain signal using the Fast Fourier Transform.

For instance, a 0.75 kW induction motor with 6202 ball bearing type having number of balls N
= 8, is taken for experimentation [50]. The harmonic vibration spectrum of the healthy motor and that with defective bearing is analyzed individually. Fig. 4(a) and Fig. 4(b) portray the vibration amplitudes for the analyzed frequencies, f1=100Hz, f2=152Hz, rotational frequency f= fr =50Hz and sideband 150-300Hz, for the motor with healthy bearing and defective bearing respectively. The vibration amplitude for faulty motor is bigger than that of a healthy motor.

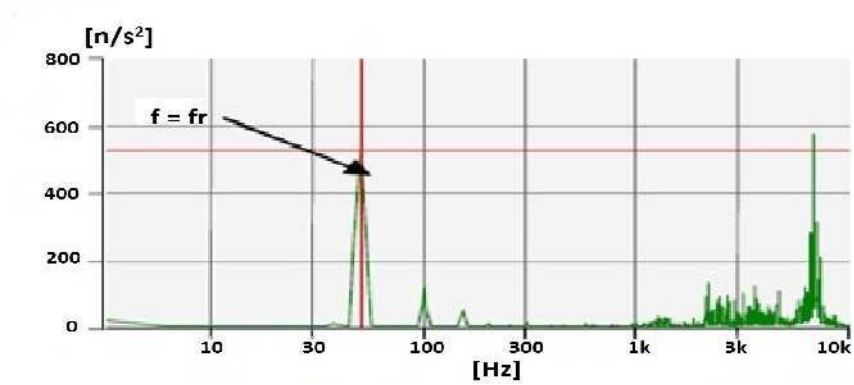


Fig. 4(a). Harmonic Vibration Spectra of Induction Motor with Good Bearing

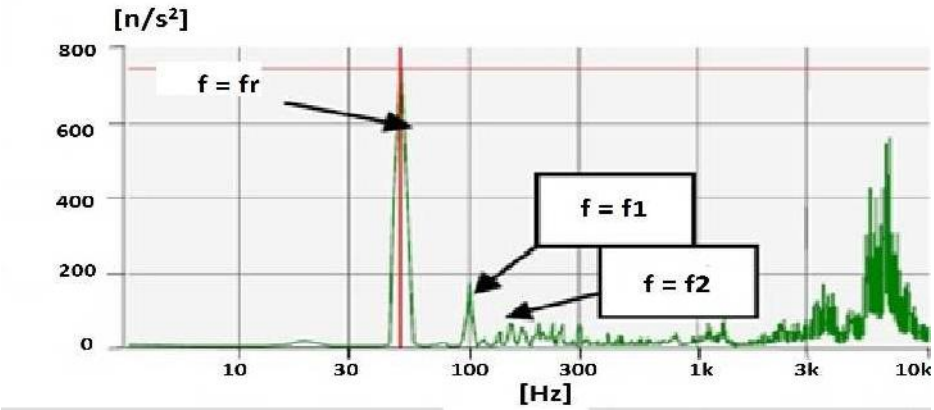


Fig. 4(b). Harmonic Vibration Spectra of Induction Motor with Bad Bearing

Dynamic Model to Simulate Bearing Faults and Analysis of Experimental Observation:

A winding function technique is used to simulate an induction motor with mixed eccentricities caused by inner race faults, and a dynamic simulation of a motor operating with bearing inner race faults is provided. Vibrations from trials on a motor with a defective bearing are contrasted with a spectrum analysis of electromagnetic torque produced by the simulated motor [51]. The power spectral density and frequency domain analysis of the vibration signal are detailed in Figures 5(a) and 5(b). After then, the spectrum magnitude is standardized to have a 0.2 Hz bandwidth. This means that the power spectral density's magnitude leaks out to adjacent frequency bins at + 0.2 Hz from the faulty frequency for any fault frequency.

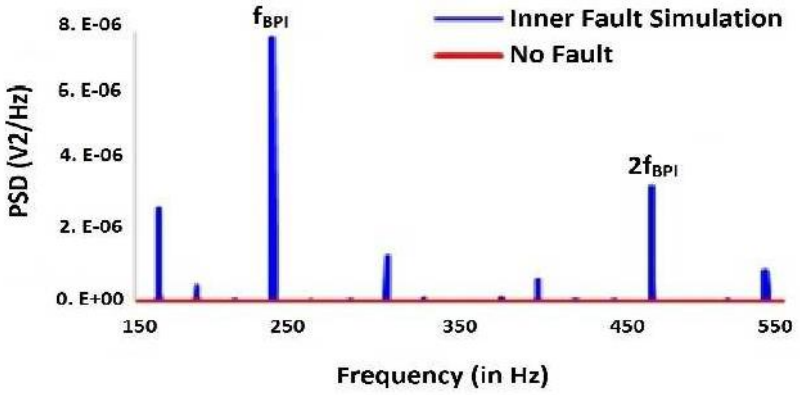


Fig.5(a). Frequency Spectrum of Electromagnetic Torque of Dynamic Simulation Motor with Bearing Fault

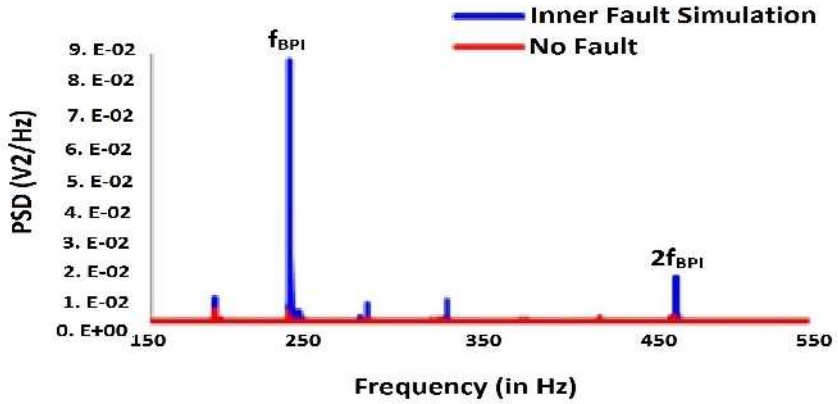


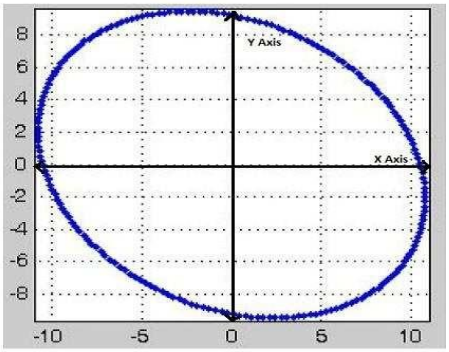
Fig.5(b). Characteristic Frequencies in the Spectral Analysis of Vibration of Induction Motor with Inner Race Bearing Fault

Detection of Stator Faults
Using Park Vector Approach and Complex Wavelets

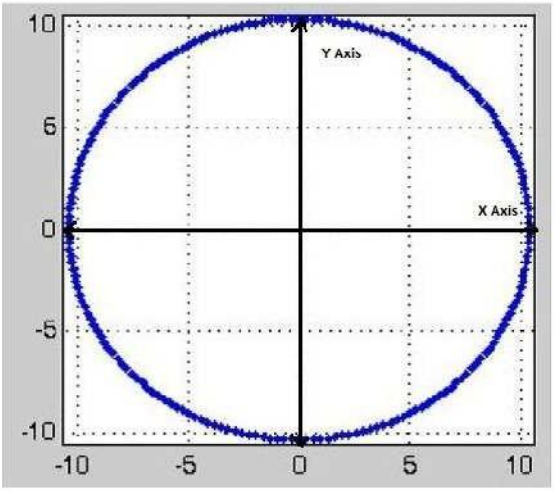
The Park vector transformation method may be used to investigate how stator defect affects machine current. Park's vector is based on the location of the instantaneous spatial vector sum of the three phase stator currents. A three-phase induction motor often doesn't need a connection to the neutral. The connection to the three-phase mains is the only thing involved. Therefore, there is no homopolar current in the mains current. Park's Transform may be used to create a two-dimensional depiction of an induction motor's three-phase current. The Park's vector components (ID, IQ) as a function of mains phase variables (Ia, Ib, Ic) are:

$$I_D = \sqrt{\frac{2}{3}} I_a - \frac{1}{\sqrt{6}} I_b - \frac{1}{\sqrt{6}} I_c$$

$$I_Q = \frac{1}{\sqrt{2}} I_b - \frac{1}{\sqrt{2}} I_c$$



A circle is mapped by this.The center of this circle is located at the coordinates' origin (0, 0). Because stator winding problems deform this region, fault detection is made simple. In addition to simplifying analysis and computations, Park's Transform outperforms



conventional techniques in terms of economy, particularly for small and medium-sized motors. Additionally, it may identify the problems without needing access to the motor.

A three-phase, four-pole induction motor model with 36 stator slots and 55 spins per slot is simulated in order to examine the suggested method [52]. Park's Transform is used to determine the Park vector currents once the three-phase supply currents are measured. Fig. 6(a) shows the Park vector of the motor current when there is no stator defect. The Park vector of the motor current in the event of a stator defect is shown in Fig. 6(b). A healthy motor's current Park's vector is a circle, but depending on the degree of defect, the form changes to an ellipse for a malfunctioning motor. Finally, complex wavelets are used to examine simulation and experimental data.

Fig.6(a). Motor Current’s Park’s Vector Representation at Healthy Case

Fig.6(b). Motor Current's Park's Vector Representation at Faulty Case

Detection of Rotor Faults and Eccentricity

Motor Current Signature Analysis (MCSA)

MCSA analyzes current harmonics in the stator current [53–59]. Due to a failure, fresh spinning flux components are responsible for these harmonics. It is based on signal processing methods such as FFT and requires just one current sensor [60]. Fig. 7 depicts the apparatus used to measure motor current. FFT is used to the stator current in order to acquire data. After FFT, the data is normalized as a function of the first harmonic amplitude and examined. Figures 8(a) and 8(b) show FFT with rotor bars in their original state and with three fractured rotor bars, respectively.

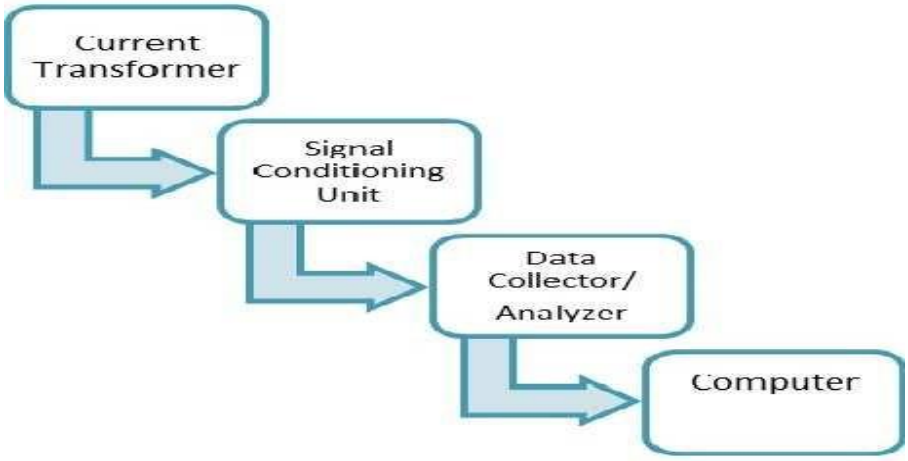


Fig.7 Set-Up for Measuring Motor Current

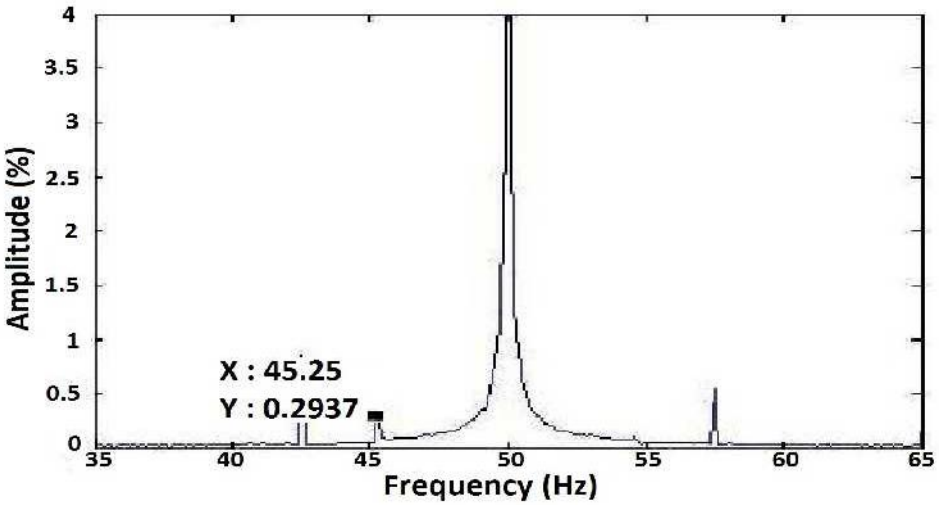


Fig. 8(a) FFT with initial condition for broken bars

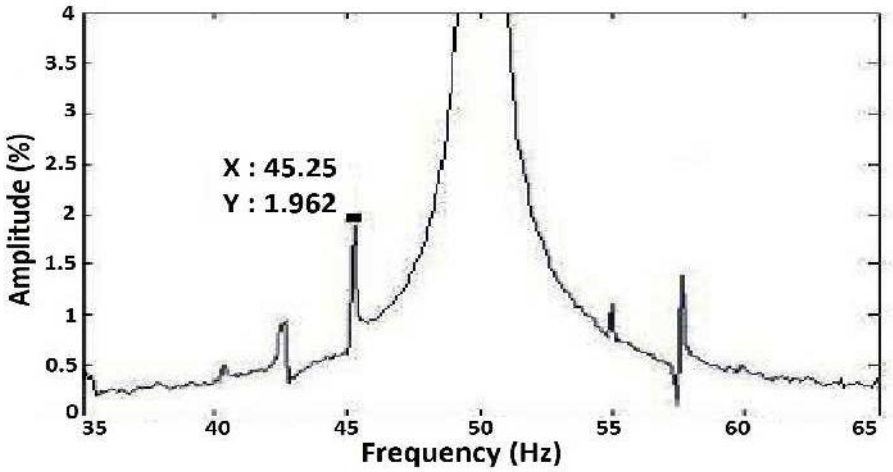


Fig .8 (b) FFT with 3 broken bars

Table 2 indicates the percentage amplitude for harmonics with different number of broken rotor bars. Evidently, the harmonic contents increase with increase in fault level i.e. rise of count of broken rotor bars.

Table 2. Results of Broken Bar Faults

Frequency(Hz)	Amplitude%	No. of Broken Bars
45.25	0.2937	0
45.25	1.028	1
45.25	1.83	2
45.25	1.962	3

Similarly, eccentricity also causes a change in the FFT of induction motor. Fig. 9(a) and Fig. 9(b) illustrate the FFT with initial condition of rotor bars and with 87.3% eccentricity respectively.

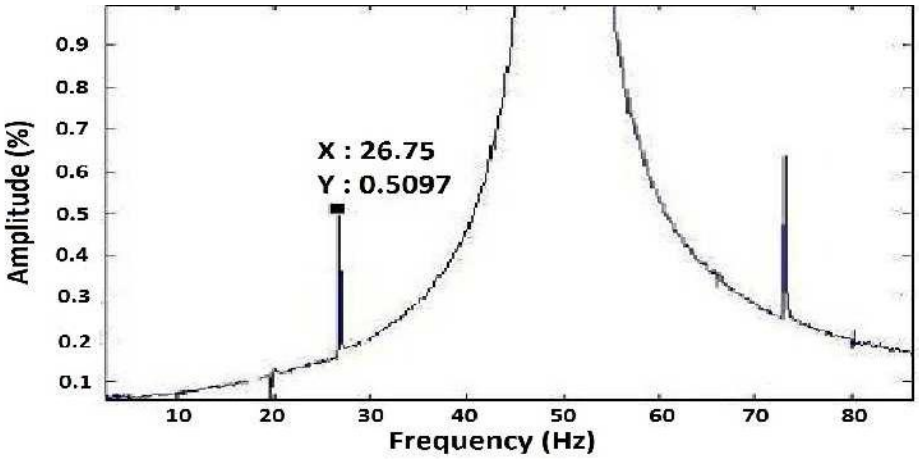


Fig. 9 (a) FFT with initial condition of Rotor's eccentricity

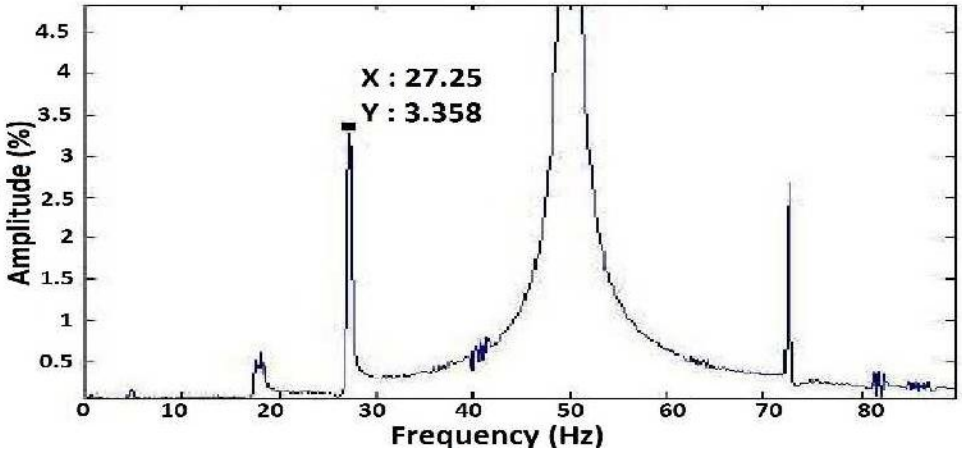


Fig. 9 (b) FFT with 87.3% of Rotor's eccentricity

Table 3 specifies the percentage amplitude for harmonics with varying levels of eccentricity. Markedly, the harmonic contents increase with increase in fault level i.e. increase of eccentricity.

Table 3. Results of eccentricity

Eccentricity (%)	**Amplitude%**
0	0.59
44.5	1.96
87.3	4.94

Intelligent Techniques

For the purpose of monitoring the status of induction motors, a number of intelligent methods have been thoroughly addressed, including fuzzy logic systems [61–63], artificial neural networks [64–66], neuro-fuzzy systems [67–69], etc. Any diagnostic method based on artificial intelligence (AI) typically consists of three main steps: i) signature extraction; ii) fault identification; and iii) fault severity estimate. A schematic of neural networks for an induction motor's condition monitoring is shown in Fig. 10 [70].

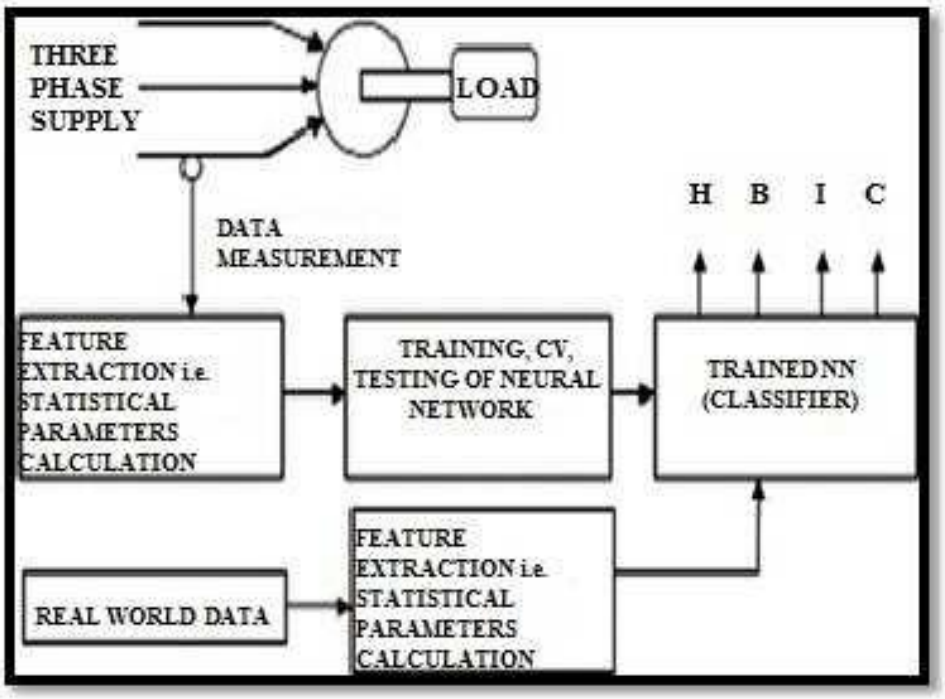


Fig. 10 Neural Network Schematic for Condition Monitoring of Induction Motor

Other approaches for the early defect detection of induction motors have also been mentioned in other works [71–77]. A detailed comparison of several fault detection methods and the defects they often identify is shown in Table 4..

Table 4. Comparison of various fault detection techniques

Fault Detection Techniques	**Detected Faults**
MCSA	Bearing, Rotor, Stator and Vibration Faults
Park's Transform	Bearing and Stator Faults
Artificial Neural Networks	Bearing and Rotor Faults
Wavelet Analysis	Bearing, Rotor, Stator and Vibration Faults
Finite Element Method	Rotor, Stator and Vibration Faults
Vibration Testing and Analysis	Bearing and Vibration Faults
Concordia Transform	Bearing Faults
External Magnetic Field Analysis	Rotor Faults
Multiple Reference Frames Theory	Eccentricity
Power Decomposition Technique	Stator Faults

KU Transformation Theory	Stator Faults
Zero Crossing Time Method	Stator Faults
Modal Analysis Method	Vibration Faults

Scope Of Future Work

Rules derived from heuristic knowledge and the connection weight of a supervised neural network may be used by expert systems to diagnose faults. Artificial neural networks and specialized expertise might improve the diagnostic monitoring system.

Additionally, a database of vibration harmonics for different sizes and design standards of three-phase induction motors may be developed by theoretical and practical research. The conventional vibration standard, which relies on the RMS velocity of vibration rather than harmonic amplitude, may be replaced with a new one using this database.

Conclusion

This essay aims to provide an overview of current advancements in the diagnosis and prognosis of induction motor faults. In this study, a variety of methods, models, and algorithms have been examined, and the applicability of a certain method for a particular fault diagnosis has been emphasized.

References

[1] G.K. "Induction Machine Drive Condition Monitoring and Diagnostic Research-A Survey," by Singh and Sa'ad Ahmed Saleh Al Kazzaz, Electric Power Systems Research, vol. 64, 2003, pp. 145-158.
[2]M. The L. "Induction Machine On-Line Condition Monitoring and Fault Diagnosis - A Survey" (AUPEC2003), Australasian Universities Power Engineering Conference, Christchurch, New Zealand, pp. 1-6, 2003; Sin, W.L. Soong and N. Ertugrul.
[3] Neelam Mehala and Ratna Dahiya's doctoral thesis, "Condition Monitoring and Fault Diagnosis of Induction Motor Using Motor Current Signature Analysis," was turned in to the National Institute of Technology's Electrical Engineering Department in Kurushetra, India, in October 2010.
[4] P. John. Tavner and J. Penman, "Condition Monitoring of Electrical Machines" (1987), Letchworth, England: Research Studies Press Ltd.
[5] Shuo Chen, "Induction Machine Broken Rotor Bar Diagnostics Using Prony Analysis," a doctoral thesis submitted in April 2008 to the University of Adelaide's School of Electrical and Electronic Engineering.
[6] Magnus Dalva and Olav Vaag Thorsen, "A survey of Faults on Induction Motors in Offshore Oil Industry, Petrochemical Industry, Gas terminals, and Oil Refineries" IEEE Transactions on Industry Applications, vol. September/October 1995, 31, no. 5.
[7] William Torbat Thomson and Mark Fenger, "Industrial Application of Current Signature Analysis to diagnose Faults in 3-Phase Squirrel Cage Induction Motors," Pulp and Paper Industry Technical Conference, Conference Record of 2000 Annual, pp. 205-211, June 19–23, 2000.
[8] "Mechanical Fault Detection in a Medium-Sized Induction Motor Using Stator Current Monitoring" by Andrew M. Knight and Sergio P. Bertani, IEEE Transactions on Energy Conversion, vol. 20, no. 4, 753–760.
[9] Neelam Mehala and Ratna Dahiya, "Condition Montoring Techniques, Induction

Machine Failure Identification and Analysis," International Journal of Circuits, Systems, and Signal Processing, vol. 3, no. 1, 2009, pp. 29–35.
[10] Mohamed El Hachemi Benbouzid, "A Review of Induction Motors Signature Analysis as a Medium for Faults Detection" IEEE Transactions on Industrial Electronics, vol. 47, no. 5, pp. 984-993, October 2000.
[11] Castelli Marcelo, Juan Pablo Fossatti, and Jose Ignacio Terra, "Fault Diagnosis of Induction Motors Based on FFT" Fourier Transform-Signal Processing, 978-953-51-0453-7, InTech, 2012.
[12] "Bearing Fault Diagnosis in Induction Machine Based on Current Analysis Using High-Resolution Technique" by Mounir Djeddi, Pierre Granjon, and Benoit Leprettre, Power Electronics and Drives, 2007.
SDEMPED in 2007. IEEE International Symposium on Electric Machine Diagnostics, 10.1109/DEMPED.2007.4393066, 2007, pp. 23-28, 2012.
[13] Van Tuan Do and Ui-Pil Chong, "Signal Model-Based Fault Detection and Diagnosis for Induction Motors Using Features of Vibration Signal in Two-Dimension Domain", Journal of Mechanical Engineering, Strojniski vestnik, vol. 57, no. 9, 2011, pp. 655-666.
[14] Aderiano M. da Silva, "Induction Motor Fault Diagnostic and Monitoring Methods," a thesis submitted in May 2006 to Marquette University's Graduate School Faculty in Milwaukee, Wisconsin.
[15] Jordi Cusidó i Roura and Jose Luis Romeral Martínez (2011), "Transient Analysis and Motor Fault Detection using the Wavelet Transform," Discrete Wavelet Transforms - Theory and Applications, Dr. Juuso T. Olkkonen (Ed.), InTech, 978-953-307-185-5.
[16]El Houssin El Bouchikhi, Vincent Choqueuse, Mohamed Benbouzid, and Jean Frederic Charpentier, "Induction Machine Bearing Failures Detection Using Stator Current Frequency Spectral Subtraction", 2012 IEEE International Symposium on Industrial Electronics (ISIE), 10.1109/ISIE.2012.6237265, pp. 1228-1233, 2012.
[17]B. Gr. Gaydon, "A device to identify rotor circuit flaws in induction motors by measuring speed fluctuations," in Proc. Instrumentation for Electric Test Measurement—Testmex Conference. Paper, 1979, pp. 5–8.
[18] J. The R. Habetler, T. G. Stack, and R. G. Harley, "Machine speed effects on rolling element bearing fault development and detection," IEEE Power Electron. Lett., vol. 1, no. 1, March 2003, pp. 19–21.
[19]C. John. Diste and R. Schiferl, "Improving trending of induction motor rms currents in process control and diagnostics using temperature, voltage, and/or speed measurements," in Proc. Industry Applications Society of IEEE. Annual Meeting Conference, vol. 1, 312–318, 1994.
[20] K. The R. Cho, J. H. Lang, and S. D. Umans, "State and parameter estimation for the detection of damaged rotor bars in induction motors," IEEE Trans. Ind. Appl., vol. 28, no. 3, May/June, pp. 702–709. 1992.
[21]F. Filippetti, C. Tassoni, G. Franceschini, and P. Vas, "Parameter estimation approach versus current spectrum approach for broken bar detection in induction machines," in Proc. Industry Applications Society of IEEE. Annual Meeting Conference, Denver, vol. 1, 95–102, 1994.
[22] P. Vas, "Parameter Estimation, Condition Monitoring, and Diagnosis of Electrical Machines" Clarendon, Oxford, UK, 1993.

[23] J. Penman, B. A. Lloyd, H. G. Sedding, and W. T. Fink, "Interturn short circuit detection and location in operating motor stator windings," IEEE Trans. Energy Conversations, vol. 9, no. 4, Dec. 1994, pp. 652–658.
[24] H. Henao, C. Demian, and G. "A frequency-domain detection of stator winding faults in induction machines using an external flux sensor," A. Capolino, IEEE Trans. Ind. Appl., vol. 39, no. 5, September/October, pp. 1272–1279. 2003.
[25] J. The F. Bangura, N. A. O. Demerdash, R. J. Povinelli, and R. H. Brown, "Diagnostics of eccentricities and bar/end-ring connector breakages in polyphase induction motors using time-stepping coupled FE-state-space techniques and time-series data mining," IEEE Trans. Ind. Appl., vol. 39, no. 4, July/August, pp. 1005–1013. 2003.
[26]A. Manoj K. Kowar, Ganguly, and H. Chandra, "Preventive Maintenance of Rotating Machines Using Signal Processing" Techniques, International Journal of Soft Computing and Engineering (IJSCE), vol. 2, no. 2, May 2012, ISSN: 2231-2307.
[27]J. Ellison, C. J. Moore, and S. J. Yang, "Methods of measurement of acoustic noise radiated by an electric machine," IEEE Proceedings, pp. 174-184, 1971.
[28] Progress in Electromagnetics Research (PIER), vol. 64, J. Faiz and B.M. Ebrahimi, "Mixed Fault Diagnosis in Three-Phase Squirrel-Cage Induction Motor Using Analysis of Air-Gap Magnetic Field"
2006, pp. 239–255.
[29] A. M. Trzynadlosky, "Using instantaneous electrical power to diagnose mechanical abnormalities in induction motors," Conference Proceedings of the 1997 International Electric Machines and Drives,
91–93, 1997.
[30]A. Ceban, V. Fireteanu, R. Romary, R. Pusca, and P. Taras, "Finite Element Diagnosis of Rotor Faults in Induction Motors based on Low Frequency Harmonics of the Near-Magnetic Field" Power Electronics & Drives (SDEMPED), 2011 IEEE International Symposium on Diagnostics for Electric Machines, 10.1109/DEMPED.2011.6063623, 2011, pp. 192-198.

[31] New York: Oxford University Press, 1999; P. Vas, Artificial—Intelligence-Based Electrical Machines and Drives: Applications of Fuzzy, Neural, Fuzzy-Neural, and Genetic Algorithm Based Techniques.
[32] M. Y. Chow, Neural Network and Fuzzy Logic Techniques for Motor Incipient Fault Identification, Singapore: World Scientific, 1997.
[33] F. Zidani, M. E. H. Benbouzid, D. Diallo, and M. S. Nait-Said, "Induction motor stator faults diagnosis by a current Concordia pattern-based fuzzy decision system," IEEE Trans. Energy Convers., vol. 18, no. 4, pp. 469–475, December 2003.
[34] Jafar Zarei and Javad Poshtan, "Bearing Fault Detection In Induction Motor Using Pattern Recognition Techniques," 2nd IEEE International Conference on Power and Energy (PECon 08), Johor Baharu, Malaysia, December 1-3, 2008, pp. 749-753.
[35] IEEE Trans. Ind. Appl., vol. 28, no. 4, pp. 921–437, July/August 1992. A. H. Bonnet, "Cause and analysis of stator and rotor failures in threephase squirrel-cage induction motors."
[36] Rotor failures in squirrel cage induction motors, A. H. Bonnett and G. C. Soukpup, IEEE Trans.

Ind. Appl., vol. IA-22, no. 6, Nov./Dec. 1986, pp. 1165–1173.
[37] "Condition Monitoring Electrical Machines" by P. J. Tanver and J. Penman, Hertfordshire, UK: Research Studies Press, 1987.
[38]M. Arkan, D.K. Perovic, and Punsworth, "Online stator fault diagnosis in induction motors," IEEE Proc-Electr. Power Appl. vol. 148, no. 6, November 2001.
[39] Arfat Siddhiqui, G.S. Yadava, and Bhim Singh, "A Review of Stator Fault Monitoring Techniques of Induction Motors" IEEE Transactions on Energy Conversion, vol. 20, no. 1, March 2005.
[40] Power Electronics & Drives (SDEMPED), 2011 IEEE International Symposium on Diagnostics for Electric Machines, 10.1109/DEMPED.2011.6063689, 2011, pp. 626-631. S. Hamdani, O. Touhami, R. Ibtiouen, and M. Fadel, "Neural Network technique for induction motor rotor faults classification –Dynamic eccentricity and broken bar faults."
[41] A. H. Bonnett, "Root Cause AC Motor Failure Analysis with a Focus on Shaft Failures," IEEE Transactions on Industry Applications, vol. 36, no. 5, September/October 2000.
[42] Subhasis Nandi, Sang Bin Lee, Thirumarai Chelvan Ilamparithi, and Doosoo Hyun, "Eccentricity Faults in Induction Machines Based on Nameplate Parameters," IEEE Transactions on Industrial Electronics, vol. 58, no. 5, May 2011.
[43] S. Nandi, R. M. Bharadwaj, and H. A. Toliyat, "Performance analysis of a three phase induction motor under incipient mixed eccentricity condition," IEEE Trans. Energy Convers., vol. 17, no. 3, pp. 392–399, September 2002.
[44] X. Li, Q. Wu, and S. Nandi, "Performance analysis of a three-phase induction machine with inclined static eccentricity," IEEE Trans. Ind. Appl., vol. 43, no. 2, pp. 531–541, March/April 2007.
[45] Pedro Vicente Jover Rodriguez, Marian Negrei, and Antero Arkkio, "A General Scheme for Induction Motor Condition Monitoring," SDEMPED 2005, International Symposium on Diagnostics for Electric Machines, Power Electronics and Drives, Vienna, Austria, September 7–9, 2005.
[46] G.B. Kliman, R.A. Koegl, J. Stein, and R.D. Endicott, "Noninvasive Detection of Broken Rotor Bars in Operating Induction Motors," IEEE Trans. Energy Conversion, vol. 3, pp. 873-879, December 1988.
[47] Joksimovic G.M. and Penman J., "The Identification of Inter-Turn Short Circuits in the Stator Winding of Operating Motors," IEEE Transactions on Industrial Applications, vol. 47, no. 5, pp. 1078-1084, October 2000.
[48]Lovi Kaushal Agrawal and SBL Tripathi, "Study of Fault Detecting Techniques in Electrical Machine", VSRD-IJEECE, vol. 1, no. 8, pp. 478-489, 2011.
[49] YE Zhongming and WU Bin, "A Review on Enduction Motor Online Fault Diagnosis," Proceedings of the Third International Power Electronics and Motion Control Conference, 2000. IPEMC 2000, vol. 3, pp. 1353-1358, 10.1109/IPEMC.2000.883050, 2000.
[50] Mariana Iorgulescu and Robert Beloiu, "Vibration and Current Monitoring for Induction Motor Fault Diagnosis," Annals of the University of Craiova, Electrical Engineering series, no. 32, ISSN 1842-4805, 2008.
[51] Dr. "Dynamic Simulation and Experimental Results of Bearing Faults of Squirrel Cage Induction Motor," Ariunbolor Purvee and Dr. Gautam Banerjee, 2012 IEEE International Conference on Condition Monitoring and Diagnosis, 23-27 September 2012, Bali, Indonesia, pp. 718-722.

[52]Dionysios V. Spyropoulos and Epaminondas D. Mitronikas, "Induction Motor Stator Fault Diagnosis Technique Using Park Vector Approach and Complex Wavelets," Electrical Machines (ICEM), 2012 XXth International Conference on, 2-5 September, pp. 1730-1734, 2012.

[53] Ruiming Fang and Hongzhong Ma, "Application of MCSA and SVM to Induction Machine Rotor Fault Diagnosis" Proceedings of the 6th World Congress on Intelligent Control and Automation, Dalian, China, June 21–23, 2006.
[54]Chiara Boccaletti, Claudio Bruzzese, Onorato Honorati, and Ezio Santini, "Rotor Bar Breakage in Railway Traction Squirrel Cage Induction Motors and Diagnosis by MCSA Technique Part II: Theoretical Arrangements for Fault-Related Current Sidebands," International Symposium on Diagnostics for Electric Machines, Power Electronics, and Drives, Vienna, Austria, September 7–9, 2005.
[55]A Alwodai, F Gu, and A D Ball, "A Comparison of Different Techniques for Induction Motor Rotor Fault Diagnosis," Journal of Physics: Conference Series 364, 012066, 2012, 25th International Congress on Condition Monitoring and Diagnostic Engineering, IOP Publishing.
[56] Neelam Mehala and Ratna Dahiya, "Motor Current Signature Analysis and its Applications in Induction Motor Fault Diagnosis" International Journal of Systems Applications, Engineering & Development, vol. 2, no. 1, 2007.
[57] Alan Miletic and Mirko Cettolo, "Frequency Converter Influence on Induction Motor Rotor Faults Detection Using Motor Current Signature Analysis – Experimental Research", Symposium on Diagnostics for Electric Machines, Power Electronics and Drives, Atlanta, GA, USA, August 24–26, 2003.
[58]D. The M. Sonje and R. "Rotor Cage Fault Detection in Induction Motors by Motor Current Signature Analysis" by K. Munje, IJCA Proceedings on International Conference in Computational Intelligence (ICCIA2012), no. 2, 2012.
[59] "Broken Bar Fault Diagnosis of Induction Motors Using MCSA and Neural Network," S. Guedidi, S.E. Zouzou, W. Laala, M. Sahraoui, and K. Yahia, 8th IEEE Symposium on Diagnostics for Electrical Machines Power Electronics Drives, no. 1, pp. 632-637, 2011.
[60] "Fault Detection and Remote Monitoring System for Induction Motors using MCSA Technique," by José Ignacio Terra, Marcelo Castelli, Juan Pablo Fossati, Marcos Andrade, Analía Conde, and Miguel Martínez-Iturralde.
[61] Mo-Yuen Chow, Sinan Altug, and H. "Fuzzy Inference Systems Implemented on Neural Architectures for Motor Fault Detection and Diagnosis" by Joel Trussell, IEEE Transactions on Industrial Electronics, vol. 46, no. 6, December 1999.
[62] Fatiha Zidani, Demba Diallo, Mohamed El Hachemi Benbouzid, and Rachid Naït-Saïd, "A Fuzzy-Based Approach for the Diagnosis of Fault Modes in a Voltage-Fed PWM Inverter Induction Motor Drive" IEEE Transactions on Industrial Electronics, vol. February 2008, 55, no. 2.
[63] Mohamed A. "Application of AI Tools in Fault Diagnosis of Electrical Machines and Drives—An Overview" by Awadallah and Medhat M. Morcos, IEEE Transactions on Energy Conversion, vol. 18, no. 2, June 2003.
[64] Paul V. Goode and MO-pen Chow, "Using a Neural/Fuzzy System to Extract Heuristic Knowledge of Incipient Faults in Induction Motors: Part I-Methodology" IEEE Transactions

on Industrial Electronics, vol. 42, no. 2, April 1995.
[65] Mo-yuen Chow, James C. Hung, and Robert N. Sharpe, "On the Application and Design of Artificial Neural Networks for Motor Fault Detection-Part I" IEEE Transactions on Industrial Electronics, vol. 40, no. 2, April 1993.
[66] "Status Review On Neural / Fuzzy Logic Techniques For Induction Motor Condition Monitoring" by Arfat Siddique, G.S. Yadava, and Bhim Singh.
[67] Y. Zhongming, W. Bin, and A.R. Sadeghian, "Electrical Machine Fault Detection using Adaptive Neuro-Fuzzy Inference," Proceedings in Joint 9th IFSA World Congress and 20th NAFIPS World Congress, pp. 390-394, 2001.
[68] Continuous online training of neural networks with applications in electric machine malfunction diagnostics, R.M. Tallam, T.G. Habetler, and R.G. Harley, IEEE 32nd Power Electronics Specialists Conference, pp. 2224-2228, 2001.
[69] "Artificial Intelligence in Engineering" by D.T. Pham and P.T.N. Pham, International Journal of Machine Tools & Manufacture, vol. 39, pp. 937-949, 1999.
[70] "Optimal MLP neural network classifier for fault detection of three phase induction motor" by Vilas N. Ghate and Sanjay V. Dudul, Expert Systems with Applications, vol.37, pp. 3468–3481, 2010.
[71] Izzet Y. O. Nel, K. Burak Dalci, and Ibrahim Senol, "Detecting bearing defects in three-phase induction motors using Park's transform and radial basis function neural networks," Sadhana vol. 31, Part 3, June 2006, pp. 235–244, June 2006.

[72] Izzet Yilmaz Nel and Mohamed El Hachemi Benbouzid, "Induction Motor Bearing Failure Detection and Diagnosis: Park and Concordia Transform Approaches Comparative Study," IEEE/ASME Transactions on Mechatronics, vol. 13, no. 2, April 2008.
[73] Kyusung Kim and Alexander G. Parlos, "Induction Motor Fault Diagnosis Based on Neuropredictors and Wavelet Signal Processing," IEEE/ASME Transactions on Mechatronics, vol. 7, no. 2, June 2002 [74] S. M. A. Cruz, H. A. Toliyat, and A. J. M. Cardoso, "Diagnosis of Stator, Rotor, and Airgap Eccentricity Faults in 38th IAS Annual Meeting, 2003, 10.1109/IAS.2003.1257725, Vol.
2, pages 1340–1346.
[75]Andrian Ceban, Raphaël Romary, and Remus Pusca, "Study of Rotor Faults in Induction Motors Using External Magnetic Field Analysis," IEEE Transactions on Industrial Electronics, vol. 59, no. 5, May 2012.
[76]Hongzhong Ma, Huamin Li, Weifang Xie, and Fen Chen, "Vibration Research on Winding Faults of Induction Motor Based on Experiment Modal Analysis Method," Hohai University, Nanjing, 210098
IPEC 2007, 2007, China. International Power Engineering Conference, 2007, pp. 366-370
[77] F. Babaa, A. Khezzar, M. Boucherma, and A. L. Nemmour, "Condition monitoring of stator faults in induction motors: Part I—Analytical investigation on the effect of the negative voltage Sequence," International Aegean Conference on Electrical Machines and Power Electronics, 2007. 10.1109/ACEMP.2007.4510503, 2007, pp. 205-210.