IJCSE International Journal of Computer Sciences and Engineering Open Access
Review Paper Vol.-6, Issue-6, June 2018 E-ISSN: 2347-2693

Paramerter Monitoring of Induction motor : A Review

Shefali Jamwal[1*], Shimi Sudha Letha[2]

[1,2]Electrical Engineering Department, National Institute of Technical Teachers Training & Research, Chandigarh, (India)

[*]*Corresponding Author:* shefalijamwal1991@gmail.com, *Tel.: +917018408526*

Available online at: www.ijcseonline.org

Accepted: 13/Jun/2018, Published: 30/Jun/2018

Abstract— A continuous parameter monitoring of machine is required in certain applications where failure of machine leads to loss of quality control, productivity and safety against catastrophic failure. Machine faults are often linked to the bearing faults. Parameter monitoring of machine involves continuous assessment on the performance of rotating components i.e. bearings, gears and motors and predicting the faults before it cause any adversity. Rotating machines are commonly used in the industry for different applications such as railways, pumps, conveyors, blowers, elevator, mining industry, etc. Parameter monitoring of rotating machines has been an important task for technicians, engineers, and researchers mainly in industrial application. This paper presents an enlarged survey on the expansion and the recent approaches in the parameter monitoring of rotating machines. In current scenario, parameter monitoring proved their ability for fault detection of incipient faults in electrical machines and equipment. Several techniques such as vibration monitoring, acoustic emission monitoring, invasive monitoring, oil monitoring are available for determining the health of rotating machines but all these monitoring methods needs expensive transducers and sensors.

Keywords— Condition monitoring, fault detection, wireless monitoring, motor currrent signature analysis.

I. INTRODUCTION

Parameter monitoring (PM) of a system is of increasing importance makes the technical availability of the system very crucial. Especially unexpected faults of equipment can cause expensive system downtime due to restricted system accessibility [I], therefore it is worth increasing the effort to monitor the system's condition in order to reduce unexpected downtime and thus operational costs. Typically the traditional PM systems need to access high-level knowledge about the system to be monitored. However, the approachability to this knowledge is difficult and often does not exist. Modeling of a system physically, with high precision due to its complex interaction among a number of dynamical subsystems, for monitoring its condition and forecast failures can infrequently be constructed [2-4].

A conventional maintenance technique in the industry has taken two types, based on fixed time interval maintenance and failure of plant as and when it happens. However, to improving the PM of induction motor using today's technology. The key elements of this new technique is condition based PM, which depends upon the parameter of the induction motor in industry [5-6]. The PM is used, to enhance the performance of the rotating machines, increasing machine life, reducing internal and external damage, reducing [7].

Parameter monitoring of rotating machines has become necessary to stop the unexpected machine shutdown. There several techniques used for PM of rotating machines such as vibration signature analysis, acoustic emission monitoring, motor current signature analysis (MCSA), but these monitoring techniques are complex and require expensive sensors [8-10]. An effective and efficient PM scheme is capable to give an early warning or predictive fault information at early stages. The PM collects primitive data information about the motor using signal processing or data analysis techniques. The major problem of this type of approach requires human interpretation [11]. The automation of the PM is the process is a logical progression of the parameter based monitoring technologies [12]. The automate fault detection and diagnostic process require an intelligent system such as fuzzy logic, genetic algorithm, artificial neural network and expert system [13]. In present days it has become necessary to monitor the machine parameters and detection of predictive failures at their inception, otherwise it may lead to unexpected machine downtime which cause big financial loss [14]. The different parameter monitoring indicators for fault analysis of dynamic machines has been explored [15].

The review paper is structured as follows: Section I provides a brief introduction about the parameter monitoring of induction motor. Section II, provides a traditionally or upcoming used techniques to the related work in the field of parameter monitoring and discussion Section III provides the conclusion.

II. RELATED WORK

In PM, complexity and cost of a monitoring system increase with number of measurements, so extensive monitoring is mainly restricted to the situations where the consequences of the poor availability, quality or yield are so severe that they clearly justify the investment in PM. Han et al was conducted a survey and reported in [16], the state-of-the-art development in the PM and fault diagnosis. Survey points out the most important benefits using intelligence and advanced signal processing techniques in development of PM schemes. Induction motor is most important prime mover in industrial application due to their high efficiency, low cost, ruggedness, high reliability. Induction machine fault detection of the induction motor based on thermal images is reported in [17].

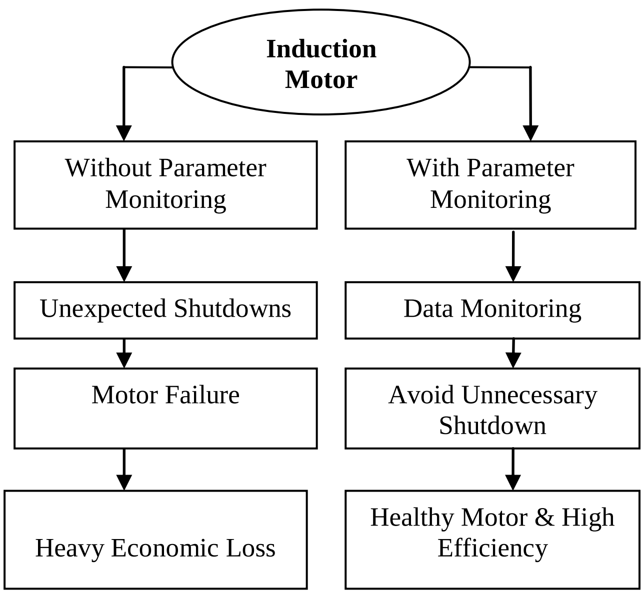

Fig. 1 Need of Condition Monitoring

In the operating condition of induction motor facing some limitations, if operating parameters are exceed then some mechanical or electrical failure will be occur in the induction motor. In many industries, may shut down, even, face a large economic loss. Hence, it is most important to monitor the cause of failure of induction motor. [18]. Therefore, various monitoring techniques for induction motor have been developed by the research to diagnose faults. In this section various PM techniques for rotating machines have been discussed [19-21]. Several organizations and research institute have already matured smart PM for the entire fleet of machines for industrial application.

A. *Vibration Monitoring*

Acquisition and subsequent processing of vibration data for rotating machinery fault diagnosis can be quite intricate; as data are usually required in three mutually perpendicular directions for accurate fault diagnosis. Several vibration monitoring approaches and data processing techniques for parameter monitoring have been explored [22-25]. In healthy conditions, induction motor produces a little vibration signal. Health monitoring of induction motor using vibration signatures has been presented [26]. Shnibha et al. presented a more reliable method for PM using vibration signatures. When a fault occurs in internal part of induction motor it generates large vibration signals [27]. Vibration signals can be detected in the term of velocity or acceleration or displacement in relative or absolute value. The survey story of fault detection in IM has been presented with different bearing faults using vibration and acoustic signals. Vibration of either the motor stator core or end caps can be easily monitored by an accelerometer which is usually directly mounted on the motor. Analysing the measured signal using traditional signal processing techniques viz. Fast Fourier Transform (FFT) does not always achieve adequate results. In Fourier transforms of a signal, it is impossible to tell when a particular event took place. An effort has been made to determine when and at what frequencies a signal event occurred [28].

B. *Motor Current Signature Analysis*

MCSA technique works by acquiring current and voltage signals from the induction motor. As a complement for MCSA, a thermal imaging technique has been used for fault detection of induction motor [29]. The signal processing techniques have been applied to the acquired current signals to produce their power spectrum profile [30]. Park et al. presented the influence of blade pass frequency (BPF) vibration in induction motor on MCSA-based RF detection [31]. The power spectrum profiles are useful in the detection of different kind of faults in the induction motor. Such current and voltage signals are measured through current and voltage sensors followed by utilizing the advance tools such as artificial neural network, fuzzy logic, digital signal processing tools, etc. MCSA technique is highly versatile for PM of the induction motors. It can easily detect these faults at an early stage and provide predictive information about the machine failure [32].

C. *Induced Voltage*

The important reasons behind the failures of rotating machines are manufacturing tolerance, their origin in design, assembly, and schedule of maintenance working environment, installation, and nature of the load on rotating machine. Induction motor, similar as other electrical rotating machines are subjected to both mechanical and electromagnetic forces [33]. So, the design and development of the induction motor is such that the interaction9between these forces under equilibrium leads to silent operation wherever in case of fault, the equilibrium is lost hence leads to further enhancement of the fault [34]. The voltage induced along the healthy condition leads to minimum noise and vibrations with a stable operation of the induction motor. When any failure or fault occurs in induction motor, the rotating shaft of the motor provides an indication to the winding or stator core [35]. The induced rotor voltage has not yet proved to be a most useful parameter for PM due to its complexity and non-reliability.

D. Temperature Monitoring

The parameter monitoring is to check the variables with regard to tolerances, and alarms, after an alarm is triggered the operator then has to take the appropriate actions. One of the most important advantages of the temperature monitoring, it need less instrumentations [36]. The temperature monitoring technique is widely in use in electrical and mechanical maintenance, agriculture, military, navy, aviation, geological survey, automotive, fault detection and it is also used in industry to detect serious faults in equipment, quality control and process control [37]. The temperature monitoring technique is also used in civil structures, water leakage, corrosion damages and welding processes, electrical installations, machineries and equipment, aerospace, food, paper mills, nuclear plant and plastic industries. A new technique of temperature monitoring technique as a non-invasive and non-contact PM & fault detection tool for Induction motor has been successfully implemented [38].

E. Air-Gap Torque Monitoring

In Induction motor, the production of air gap torque depends on the current and flux linkages. The air-gap torque can be9measured, while the induction motor in running condition. It is laborious to measure the air-gap torque directly [39]. Silva et al. presented a Finite Element Analysis (FEA) in the estimation of air- gap torque observation of the induction motor under standard supply systems at different frequencies [40]. The analysis of air gap torque can be done, if differentiated the faults of unbalance stator winding and rotor bar. This can be economically attractive to industrial application, where an unwanted shut down, even facing a heavy economic loss in production of plant.

F. Noise Monitoring

Noise monitoring works with ultrasonic and audible frequencies monitoring techniques. The method can be implemented for bearing and rotor related defects. Bearing faults, gear faults and motor faults can be detected using acoustic sensors. When working with ultrasonic wave, it has ability to monitor the stator related faults [41]. However, in all PM techniques, various actuators and sensors are used to gather vibration data from the machine. Nistor et al. presented a fault diagnostics of low speed bearing with a new acoustic emission based techniques that allows noise signals to be the acquired sampled at a rate comparable to vibration based PM [42]. From the literature, it has been observed that the acoustic emission based monitoring techniques is less efficient with compare to other PM techniques [43].

G. Speed Fluctuations Monitoring

The speed fluctuations monitoring is a technique that can detect failure or defects using speed fluctuations in the operational period of the rotating machines. This technique can be utilized for detecting the rotor faults in induction motor [44]. Traditionally used techniques are air-pap eccentricity, vibrations, rotor asymmetry, and misalignment.. In normal rotor bar, current fluctuates sinusoidally with the slip frequency, provide a contribution to developing the torque that will vary sinusoidally with twice the slip frequency [45]. A defected rotor bar will not contribute to the shaft torque.

Table-1 Comparison of Different PM Techniques

Techniques	**Insulation**	**Stator Winding**	**Rotor winding**	**Eccentricity**	**Bearing Damage**
Vibration	-	-	✓	✓	✓
MCSA	-	✓	✓	✓	✓
Induced Voltage	✓	✓	✓	✓	✓
Temperature Monitoring	✓	✓	✓	✓	✓
Air-Gap Monitoring	-	-	-	✓	✓
Noise Monitoring	-	-	✓	✓	✓
Speed Fluctuations Monitoring	-	✓	✓	✓	✓
Magnetic Flux Monitoring	-	✓	✓	✓	-

For the rotor, the resulting torque can be divided into two components in which one is constant and other is which varies with twice slip frequency. Mostly, the induction motor has variable load torque, the used instruments are capable of distinguishing between load fluctuations and fluctuations of twice slip frequency indicating rotor faults in induction motor [46].

H. Magnetic Flux Monitoring

In induction motors, the magnetic flux in the air-gap during healthy conditions varies sinusoidally with space or time. Related problems to rotor and stator faults cause deviations from the sinusoidal variations [47]. The rotor faults can be easily identified using a search coif fixed to its stator part. The changes in the air-gap flux density caused by the stator or rotor will produce an axial flux that can be easily detected by a measuring coil around the rotating shaft or other sensors [48]. Failures are directly revealed to the analysis of the frequency spectrum of the machine or motor signal that can be acquired by the different acquisition techniques. The monitoring of the axial leakage fluxes is possible to detect the various asymmetries and abnormalities such as stator inter-tum failure, broken rotor bars, bearing related problems, eccentricity faults, misalignment and so on [49].

III. CONCLUSION

PM of rotating machines has evolved with the advent of sensing data analytics platforms, machine diagnostic methods, and information management. The developments of the monitoring technologies enhance to obtain the automation monitoring systems for the overall deployment of the industrial plant. In this paper, the state-of-the-art-review on parameter monitoring of rotating machines has been reviewed which is useful for orienting new research in the field of condition based monitoring of induction motor and other electrical rotating machines.

MCSA, the most popular technique, provides sensor less diagnosis of some motor problems but it’s not so effective for the industrial applications where the load will constantly change on rotating machine. Time-frequency analysis has been investigated vastly in recent years but its heavy hardware requirements and high complexity are limitations for the low-cost monitoring systems.

Motor power analysis because of need to both currents and voltages simultaneously and dependence on the drive inertia has some limitation. Most of recurring problems in rotating machinery like misalignments can be identified by vibration analysis. The measured vibration and associated current harmonics are closely correlated. By detection ozone, carbon monoxide and others in the coolant oil monitoring technique, some faults like insulation degradation can be detected easily. Also, temperature monitoring is introduced as efficient tools for parameter monitoring of motors.

REFERENCES

[1] Tarek Aroui, Yassine Koubaa, and Ahm Toumi, “Magnetic Coupled Circuit Modelling of Induction manchies oriented to Diagnostics”, Leonardo Journal of sciences, issue 13, pp.103- 121, Dec.2008.

[2] Mohamed Boucherma, Kaikaa, and Khezzar, “Park Model of squirrel cage Induction Machine including space harmonic effects”, Journal of Electrical Engineering, pp. 193-199, 2006.

[3] Mark M. Hodowanec, William R.Finiey, Scott and W. Kreitzer, “Motor field protection and recommended settings and monitoring”, IEEE.pp. 271-284, 2002.

[4] C.M. Riley, B.K. Lin, T.G. Habetler and G.B. Kliman, “Stator Current Harmonics and their Causal Vibrations: A Preliminary Investigation of Sensorless Vibration Monitoring Applications,” IEEE Trans. on Ind. Appl., vol. 35, no. 1, pp. 94-99, Jan./Feb. 1999.

[5] M.Y.Chow, Robert N Sharpe and James C Hung, “ On the Application and Design of Artificial Neural Networks for motor fault detection – Part I”, IEEE Transactions on Industrial Electronics, Vol. 40, No 2 , pp 181- 188, April 1993.

[6] P.V.Goode, M.Y.Chow, “Using a Neural/Fuzzy system to extract Heuristic knowledge of incipient faults in I.M: part IMethodology”, IEEE transactions on industrial Electronics, Vol. 42, No.2, 131-138, April 1995.

[7] J. F. Martins, V. Fernao Pires, and A. J. Pires,“ Unsupervised Neural-Network-Based Algorithm for an On-Line Diagnosis of Three- Phase Induction Motor Stator Fault”, IEEE Transactions On Industrial Electronics, Vol. 54, NO. 1, February, pp. 259-264, 2007.

[8] Y. Han and Y. H. Song, "CM techniques for electricalequipment: a literature survey," IEEE Power Engineering Review, vol.22, pp. 59-59, 2002.

[9] P. Tavner, ”Review of condition monitoring of rotating electrical machines," IET Electric Power Applications, vol. 2, no. 4, pp. 215-247, 2008.

[10] O. Duque-Perez, D. Morinigo-Sotelo, and M. Perez- Alonso, "Diagnosisof induction motors fed by supplies with high harmonic content usingmotor current signature analysis," International Conference on PowerEngineering, Energy and Electrical Drives, pp. 1- 6, 2011.

[11] W. T. Thomson and M. Fenger, "Case histories of current signatureanalysis to detect faults in induction motor drives," IEEE InternationalElectric Machines and Drives Conference, vol.3, pp. 1459-1465, 2003.

[12] J. Ilonen, J.-K. Kamarainen, T. Lindh, J. Ahola, H. Kalviainen, and J. Partanen, \Diagnosis tool for motor condition monitoring," IEEE Transactions on Industry Applications, vol. 41, no. 4, pp. 963{971, 2005.

[13] R. R. Schoen, T. G. Habetler, F. Kamran, and R. G. Bartfield, "Motorbearing damage detection using stator current monitoring," IEEETransactions on Industry Applications, vol. 31, pp. 1274-1279, 1995.

[14] C. Ranga and A. K. Chandel, “Advanced tool based condition monitoring of induction machines by using labviewa review," in Electrical Computer and Electron- ics (UPCON), 2015 IEEE UP Section Conference on pp. 1-6, IEEE, 2015.

[15] Y. Han, Y.H. Song. CM techniques for electrical equipment—A literature survey. IEEE Trans. Power Deliv. Vol. 18, pp. 4-13, 2003.

[16] J. L. H. Silva and A. J. M. Cardoso, "Bearing failures diagnosis in three phase induction motors by extended Park's vector approach," 31st Annual Conference of IEEE Industrial Electronics Society, pp. 6 , 2005.

[17] J. R. Stack, T. G. Habetler, and R. G. Harley, "Fault classification andfault signature production for rolling element bearings in electricmachines," IEEE Transactions on Industry Applications, vol. 40, pp.735- 739, 2004.

[18] C. Bianchini, F. Immovilli, M. Cocconcelli, R. Rubini, and A. Bellini,"Fault detection of linear bearings in brushless ac linear motors byvibration analysis," IEEE Transactions on Industrial Electronics, vol.58, pp. 1684- 1694, 2011.

[19] M. E. H. Benbouzid, "A review of induction motors signature analysisas a medium for faults detection," Proceedings of the 24th AnnualConference of the IEEE Industrial Electronics Society, vol.4, pp. 1950-1955, 1998.

[20] M. Pineda-Sanchez, R. Puche-Panadero, M. Riera- Guasp, A. Sapena-Bano, J. Roger-Folch, and J. Perez- Cruz, "Motor CMof induction motor with programmable logic controller and industrialnetwork," Proceedings of the 2011-14th European Conference onPower Electronics and Application, pp. 1-10, 2011.

[21] G. Singh and S. A. S. Al Kazzaz, "Induction machine drive condition monitoring and diagnostic researcha survey, Electric Power Systems Research, vol. 64, no. 2, pp. 145-158, 2003.

[22] W. Li and C. K. Mechefske, \Detection of induction motor faults: a comparison of stator current, vibration and acoustic methods," Journal of vibration and Control, vol. 12, no. 2, pp. 165{188, 2006.

[23] V. Patel, N. Tandon, and R. Pandey, "Defect detectio in deep groove ball bearing in presence of external vibration using envelope analysis and duffing oscillator," Measurement, vol. 45, no. 5, pp. 960{970, 2012.

[24] C. Vaithilingam and G. Thio, "Health monitoring of induction motor for vibration," Journal of Electrical Engineering, pp. 1-8, 2015.

[25] A.K.Verma, S. Sarangi, and M.H. Kolekar. Misalignment fault detection in induction motor using rotor shaft vibration and stator current signature analysis. International Journal of Mechatronics and Manufacturing Systems, vol. 6(5-6), pp.422-436, 2013.

[26] R. Shnibha, A. Albarbar, A. Abouhnik and G. Ibrahim. A more reliable method for monitoring the condition of three-phase induction motors based on their vibrations. ISRN Mechanical Engineering, 2012.

[27] I. Sudhakar, S. AdiNarayana and M. AnilPrakash. Condition Monitoring of a 3-Ø Induction Motor by Vibration Spectrum anaylsis using Fft Analyser-A Case Study. Materials Today: Proceedings, vol. 4(2), pp.1099-1105, 2017.

[28] A. Ruiz-Gonzalez, F. Vargas-Merino, "Application of Slope PWM Strategies to Reduce Acoustic Noise Radiated by Inverter-Fed Induction Motors," in IEEE Trans. on Industrial Electronics, vol. 60(7), pp. 2555-2563, 2013.

[29] A.G. Garcia-Ramirez, L.A. Morales-Hernandez, R.A. Osornio-Rios, A. Garcia-Perez and R.J. Romero-Troncoso. Thermographic technique as a complement for MCSA in induction motor fault detection. In Electrical Machines (ICEM), 2014 International Conference on (pp. 1940-1945). IEEE, 2014.

[30] Y. Park, M. Jeong, S.B. Lee, J.A. Antonino-Daviu and M. Teska. Influence of blade pass frequency vibrations on MCSA-based rotor fault detection of induction motors. IEEE Transactions on Industry Applications, vol. 53(3), pp. 2049-2058, 2017.

[31] S. Haus, H. Mikat and M. Nowara, S. T. Kandukuri, U. Klingauf, and M. Buderath: Fault Detection based on MCSA for a 400Hz Asynchronous Motor for Airborne Applications, International Journal of Prognostics and Health Management, 2013

[32] A. Singhal and M. A. Khandekar, "Bearing fault detection in induction motor using motor current signature analysis", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 2, no. 7, pp. 3258–3264, 2013.

[33] S.S. Tijare, G.D. Thakare, R.P. Argelwar. "Multi-purpose DC high voltage generator using CockcroftWalton voltage multiplier circuit" International Journal for scientific Research and development, vol. 2(12), 2015.

[34] M. Nikhil, R. Waghamare, P. Argelwar, A. Thakare and S. Urkude. "Battery Operated Multistage High voltage generation by using CockcroftWalton multiplier," International Journal of Engineering Sciences & Research Technology, vol. 4(3) 2015

[35] R.S. Marino, S. Peresada and P. Valigi, ‘‘Adaptive Input-Output Linearizing Control of Induction Motor’’, IEEE Transaction on Automatic Control, vol. 38(2), pp. 208-221, 2014.

[36] A. Glowacz and Z. Glowacz, "Diagnosis of the three-phase induction motor using thermal imaging," Infrared Phys. Technol., vol. 81, pp. 7–16, 2017.

[37] A. G. Garcia-Ramirez, L. A. Morales-Hernandez, R. A. Osornio-Rios, J. P. Benitez-Rangel, A. Garcia-Perez, and R. D. J. Romero-Troncoso, "Fault detection in induction motors and the impact on the kinematic chain through thermographic analysis," Electr. Power Syst. Res., vol. 114, pp. 1–9, 2014.

[38] G. T. Singh, C. Anil Kumar, and V. N. A. Naikan, "Induction motor inter turn fault detection using infrared thermographic analysis," Infrared Phys. Technol., vol. 77, pp. 277–282, 2016.

[39] V. V. Thomas, K. Vasudevan, and V. J. Kumar, "Use of air-gap torque spectra for squirrel cage rotor fault identification", 4th IEEE Int. Conf. PIower Electron. Drive Syst. IEEE PEDS 2001 - Indones. Proc. (Cat. No.01TH8594), India, vol. 2, pp. 484– 488, 2001.

[40] A. M. da Silva, R. J. Povinelli, and N. A. Demerdash, "Rotor bar fault monitoring method based on analysis of air-gap torques of induction motors", IEEE Transactions on Industrial Informatics, vol. 9(4), pp. 2274– 2283, 2013.

[41] A. Ruiz-Gonzalez, F. Vargas-Merino, "Application of Slope PWM Strategies to Reduce Acoustic Noise Radiated by Inverter-Fed Induction Motors," in IEEE Trans. on Industrial Electronics, vol. 60(7), pp. 2555-2563, 2013.

[42] C.G. Nistor, "Analysis of noise and heating for three-phase induction motor fed by inverter," Proc. of the 14th International Conference on Optimization of Electrical and Electronic Equipment, Braşov, Romania, pp. 389-396, 2014. [Online]. Available: http://dx.doi.org/ 10.1109/OPTIM.2014.6850931.

[43] S.A. Mortazavizadeh, A. Vahedi and A. Zohouri. "Detection of Stator Winding Inter-turn Short Circuit In Induction Motor Using Vibration Specified Harmonic Amplitude", 2nd International Conference on Acoustics & Vibration (ISAV2012), Tehran, Iran, 26-27 Dec. 2012.

[44] F. Filipetti, G. Franceschini, C. Tassoni, and P. Vas, "EAI techniques in induction machine diagnosis including the speed ripple effect," IEEE Transactions India Applications, vol. 34(1), pp.98-108, 1998.

[45] J.R. Mountain, "Fuzzy logic Motor Speed Control with Real-Time interface using 8-bit Embedded Processor," 42nd South Eastern Symposium on System Theory, March 2010.

[46] F. Rashidi. Sensorless speed sontrol of induction motor drives using robust and adaptive neuro-fuzzzy based intelligent controller",IEEE international conference on industrial technology (ICIT), pp. 617- 627, 2004.

[47] L. Frosini, A. Borin, L. Girometta et al., "A novel approach to detect short circuits in low voltage induction motor by stray flux measurement", Proc. Int. Conf. Electrical Machines (ICEM), pp. 1538-1544, 2012.

[48] L.P.C.M. Filho, R. Pederiva, J.N. Brito, "Detection of stator winding faults in induction machines using flux and vibration analysis", Mech. Syst. Signal Process., vol. 42(1), pp. 377-387, 2014.

[49] R. Romary, R. Pusca, J.P. Lecointe et al., "Electrical machines fault diagnosis by stray flux analysis", *Proc. Int. Conf. Electrical Machines Design Control and Diagnosis (Wemdcd)*, pp. 247-256, 2013

Author's Profile

Mrs Shefali Jamwal is presently working as Assistant Professor in Electrical Engineering Department at TRAMIET College Nerchowk, Distt Mandi Himachal Pradesh, she has 5 years of teaching experience. She earned her bachelor of Electrical Engineering from Green Hills Engineering Kumarhatti, Himachal Pradesh and pursuing Master of Engineering from NITTTR Chandigarh. Her area of specialization is Instrumentation and Control. Email:- shefalijamwal1991@gmail.com

Mrs Shimi S.L is presently working as Assistant Professor, Electrical Engineering Department, NITTTR, and Chandigarh. She has 14 years of experience out of which 13 years are of teaching and 1 year is of Industrial. Mrs. Shimi S.L earned her Bachelor of Electrical and Electronics Engineering from J.J College of Engineering and Technology, Trichy, Tamil Nadu and Master of Power Electronics and Drives from Saranathan College of Engineering, Trichy, Tamil Nadu and pursing her Ph.D from PEC University of Technology, Chandigarh. Up till now he has guided more than 40 students for BE and 30 students for Masters Degree. She has more than 120 Research Articles to her credit. Her areas of specialization are Power Electronics, Digital Electronics, ANN, Fuzzy, ANFIS etc. Mrs. Shimi S.L is a Member of IEEE (USA) and ASME (USA). E-mail: shimi.reji@gmail.com