ISSN 2348-1196 (print)
International Journal of Computer Science and Information Technology Research ISSN 2348-120X (online)
Vol. 3, Issue 3, pp: (309-313), Month: July - September 2015, Available at: www.researchpublish.com

Motor Current Signature Analysis as a Tool for Induction Machine Fault Diagnosis

[1]Alka Thakur, [2]Dr. S. Wadhwani, [3]Dr. A.K. Wadhwani

1Department of Electrical Engineering, Bhabha Enggineering & Research Institute, Bhopal

2 Department of Electrical Engineering, Madhav Institute of Science & Technology, Gwalior

3Department of Electrical Engineering Madhav Institute of Science & Technology, Gwalior

---

Abstract: **Rotating electrical machine plays an important role in electrical industry. Of all the motors the role of induction motors in industry has been greatly increased due to their simple construction, reliability, robustness and easy maintenance. Various faults like stator faults, broken rotor bar faults, rotor eccentricity, winding and bearing faults can occur during normal operation of the motor. Since the motor current plays a vital role for detecting the incipient fault, the Motor Current Signature Analysis (MCSA) is considered to be the most popular fault detection method to detect the common machine fault. The subject of fault detection and monitoring has been the focus of many investigations and research and still, improved techniques are to be researched for reliable performance and improved efficiency. This literature presents the basics of MCSA as a tool for detecting the health of the electrical machine.**

Keywords: **Induction machine, fault detection, Condition monitoring, Motor Current Signature Analysis.**

I. INTRODUCTION

With the industrial growth and development of advanced adjustable speed drives it has become necessary to monitor the condition of induction motors. The behavior of induction during abnormal conditions and the possibility to diagnose these conditions have been a challenging subject for many electrical machine researchers. The monitoring of the health of running electrical motors not only prevents severe economic losses resulting from catastrophic failures but also improve production, system reliability and maintenance. As the induction machine is highly symmetrical, any change in the interaction of flux between the stator and rotor results in changes to the stator voltages, current, vibration and electromagnetic field. Hence the symmetry of motor is affected giving rise to machine faults such as turn to turn short circuit, broken rotor bars, bearing deterioration etc. In order to obtain increased production, high efficiency and better performance it has become necessary to monitor the condition of the motor under operation. Various techniques for the detection of these faults have been researched and developed for several years for diagnosis of the health of the induction machine. Many researchers nowadays used online signals based monitoring system for condition monitoring of the motor under operation and to decide whether to remove the motor from the drive system or to improve its health based on the information received from the condition monitoring system. The main objective of this literature is to for condition monitoring of electrical machines through motor current signature analysis for present a procedure to acquire and analyze current signals improved efficiency in the production system. Basically the faults can be analyzed in terms of Rotor faults (broken rotor bars), Stator faults, Dynamic eccentricity, and Static eccentricity, Inter turn short circuits and cracked or bent shaft. This can be easily analyzed through the classification summarized below in fig. 1.

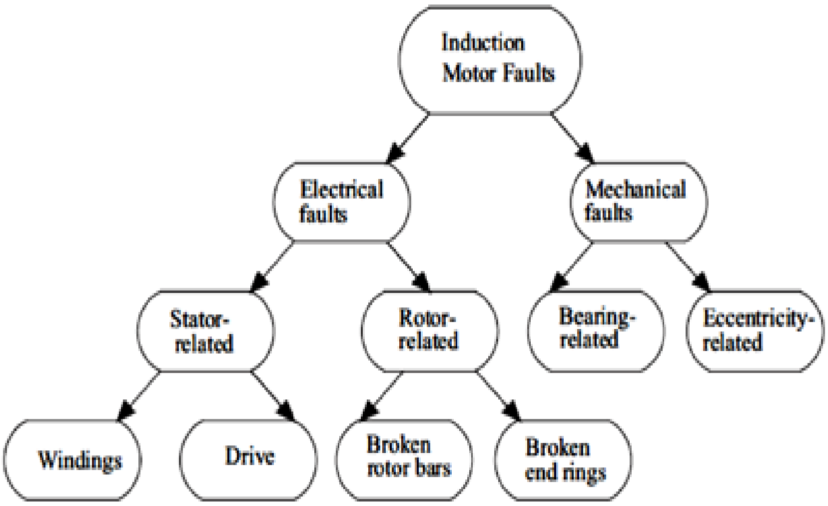

Fig.1 Classification of Induction Machine faults machine faults

II. MOTOR CURRENT SIGNATURE ANALYSIS

In the present era of increasing demand for prediction technology, a recent technique commonly abbreviated as Motor current signature analysis (MCSA) is attracting more attention of industries as well as researchers. Motor current signature analysis (MCSA) is a noninvasive fault detection technique based on frequency in which one or various specific frequencies are used as fault indicators and this technique is capable of detecting and analyzing stator winding faults. By means of the motor signature, the user can identify the magnitude and frequency of each individual component that constitutes the signal of the motor. This signature is composed of magnitudes of frequencies of each individual component extracted from their signals of current or voltage. The MCSA is performed by monitoring the activation of some specific fault condition related to harmonics. With the help of MCSA it is possible to analyze the health of stator winding, shorted turns in the low voltage stator windings in the rotor winding, static and dynamic air gap eccentricities, overall system load analysis, efficiency and coupling health.

Set up for MCSA: Since this technique is used for the online condition monitoring of current signals for the motor under operation, it is necessary to have the instrumentation set up for online recording of the signals of the motor current. It comprises of :

i. A current transformer for sensing current signals.

ii. A resistive shunt across the output of the current transformer.

iii. A spectrum analyzer to produce current signature.

III. INDUCTION MACHINE FAULT DETECTION

3.1 Detection of broken rotor bars faults:

When a 3 phase symmetrical stator winding is fed from symmetrical supply, will produce a resultant forward rotating magnetic flux at synchronous speed and if there, exact symmetry exists, there will be no backward rotating field due to the fact that any asymmetry in the stator winding impedance will produce a resultant backward rotating field from the stator winding. Hence with this concept as applicable to the rotor winding, the very first difference compared to the stator winding is that the frequency of the induced electro-magnetic force and current in the rotor winding is at slip frequency, i.e. s.f1, and not at the supply frequency. The rotor currents in a cage winding produce an effective 3-phase magnetic field with the same number of poles as the stator field but rotate at a slip frequency f2= s.f1 with respect to the rotating rotor. In case of symmetrical cage winding, only a forward rotating field exists, whereas in case of rotor asymmetry ,then there will also be a resultant backward rotating field at slip frequency with respect to the forward rotating rotor. And hence, the backward rotating field with respect to the rotor induces a current and e.m.f. in the stator winding at frequencies

$fsb=f1(1-2s)hz$ eq.(1)

This is referred to as the lower twice slip frequency sideband due to broken rotor bars. Therefore there is a cyclic variation of current that causes a torque pulsation at twice slip frequency (2sf1) and a corresponding speed oscillation, which is also a function of the drive inertia. These speed oscillations can however reduce the magnitude of the f1 (1-2s) sidebands but an upper sideband current component at f1 (1+2s) is induced in the stator winding due to the rotor oscillation. The upper sideband is enhanced by third time harmonic flux. Broken rotor bars therefore results in current components being induced in the stator winding at frequencies

$fsb = f1(1 \pm 2s)$ hz eq (2).

These frequencies are the classical twice slip frequency sidebands arise due to broken rotor bars.

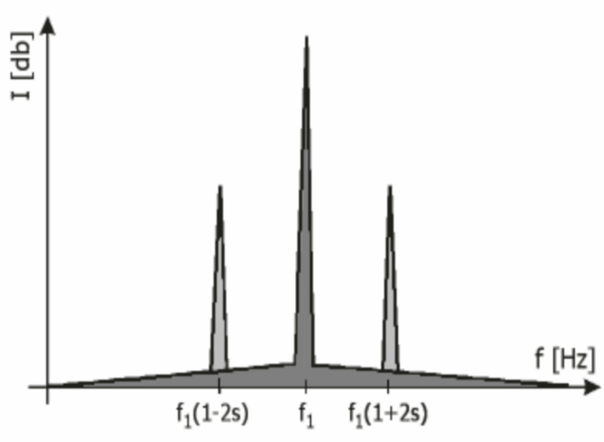

Fig.2 An idealized current spectrum

3.2 Detection of air gap eccentricity faults:

Air gap eccentricities are of two types viz: Static eccentricity and dynamic eccentricity. The Static eccentricity is the evolution of uneven stator-rotor air gap caused due to the presence of cooked bearing or improper adjusted air gap for plain bearings.

Static eccentricity is characterized by a displacement of the axis of rotation where the position of the minimal air gap length is fixed in space. It can be caused by the incorrect positioning of the rotor or stator at the commissioning stage. Since the rotor is not centered within the stator core, the field distribution in the air gap is unsymmetrical. The non-uniform air gap gives rise to a radial force of electromagnetic origin, called unbalanced magnetic pull commonly abbreviated as (UMP), which acts in the direction of minimum air gap. Sometimes the static eccentricity may be a cause of dynamic eccentricity. Dynamic eccentricity is the generation of variable stator –rotor air gap due to the wear out of bearing housings and end covers due to which rotor stars rubbing with the stator. The dynamic eccentricity means that the rotor is not rotating on its own axis and the minimum air gap rotates with the rotor. This kind of eccentricity may be caused by a bent shaft, mechanical resonances, bearing wear and misalignment or even due to static eccentricity .Therefore, the non-uniform air gap of a certain spatial position is sinusoidally modulated and results in an asymmetric magnetic field thus gives rise to a revolving UMP. Dynamic eccentricity is function of space and time. Air gap eccentricity in induction machines causes characteristic harmonic components in electrical quantities which can be analyzed through spectral analysis of motor current under operation. With the help of current signature pattern through MCSA it is possible to analyze the abnormal patters of air gap eccentricity and then trending those patterns with the equation given below.

$fec = f1\{(R \pm nd)(1-s/p) \pm nws\}$ *eq. (3)*

Where

- fec is the frequency components that are a function of air gap eccentricity(hz)
- R is the no. of rotor slots
- f1 is the supply frequency (hz)
- nd=±1

- nws=1,3,5,7
- s is the slip and
- p is pole pairs

Thus the above eq. with nd =0 gives the classical rotor slot passing frequency components where the series of components are placed at twice the supply frequency 2f1 apart distance. Similarly with nd=±1 we receives the additional components which were initially supposed to be only a function of dynamic eccentricity. But researches proves that as the static eccentricity increases the components that were supposed to be the function of only dynamic eccentricity ,also increases in terms of magnitude as stated earlier that sometimes static eccentricity is also a cause of dynamic eccentricity. Thus the signature pattern of specific rotor slot passing frequency can be determined with the above equation.

3.3 Detection of faults due to mechanical influences:

The air gap flux changes due to the change in air gap eccentricity. Any mechanical disturbance to the rotor of the induction motor leads to changes in the air gap flux waveform. Consequently this can induce stator current components as,

$fe= f1\pm mfr$ eq.(4)

where,

- fr = rotational speed frequency of the rotor,(hz)
- m = 1, 2, 3 .... harmonic number,
- fe = current components due to air gap disturbance, hz.

This means that the effects of mechanical disturbances produced from, for example, shaft coupling misalignment, slow speed gearboxes, fluid couplings, , bearing wear, belt drives, roller element bearing defects and mechanical problems that result in dynamic rotor disturbances can induce current components, which can be easily analyzed due to changes in the current spectrum.

3.4 Detection of faults due to shorted turns in LV Stator windings:

The stator current components induced due to changes in the rotating flux wave can be used to diagnosis shorted turns in LV winding of the stator. This can be accomplished by detecting the frequency components as stated by,

$fst = f1\{n/p(1-s)\pm k\}$ eq. (5)

Where,

- f1= supply frequency, n =1, 2, 3..,
- fst = components that are a function of shorted turns,
- p = pole pairs,
- s= slip

IV. CONCLUSION

In this increasing demand for prediction technology, a specific technique referred to as motor current signature analysis (MCSA) is drawing more attention of industries .This literature summarizes the fundamentals of MCSA and demonstrates how motor current signature analysis can reliably used to diagnose faults mainly related to stator and rotor of induction motor drives. The signs of current or voltage signals of one or three phases of the machine produce, after analysis, as the signature of machine, specify its operating pattern. This signature or pattern is composed of magnitudes of frequencies of each individual component extracted from their current or voltage signals. In this technique known as Motor Current Signature Analysis (MCSA), the current signal can be easily acquired from one phase of the motor supply without interrupting the machine operation. This characteristic permits identifying patterns in the signature and justify healthy motors from unhealthy one. Apart from other techniques this technique (MCSA) is considered and recommended by most of the researchers as the most sophisticated and reliable method for fault diagnosis and is utilized by many industries. The response obtained allows the user to identify whether the machine is ‘healthy’, “unhealthy” or in which particular part of the motor lies the fault in order to prevent the machine from catastrophic failures.

V. FUTURE EXPANSION

MCSA technology can be used in conjunction with other technologies, such as motor circuit analysis, in order to provide a complete overview of the motor circuit.

REFERENCES

[1] Tavner, P.J. Ran, L., Penman, J. & Sedding,H.(1987).Condition Monitoring of Rotating Electrical Machines, The Institution of Engineering and Technology – IET, 2nd Edition, ISBN 978-0863417412, London, UK.

[2] Thomson, W.T.,& Fenger, M. (2001).Current Signature Analysis to Detect Induction Motor Faults, IEEE Industry Applications Magazine, Vol.7, No.4, (July 2001), pp. 26-34, ISSN 1077-2618.

[3] J Penman, H G Sedding, B A Lloyd and WT Fink: "Detection and Location of Interturn Short Circuits in the Stator Windings of Operating Motors", IEEE Transactions on Energy Conversion, Vol. 9, No 4, December 1994.

[4] Benbouzid, M.H. (2000). A Review of Induction Motors Signature Analysis as a Medium for Faults Detection, IEEE Transactions on Industrial Electronics, Vol.47, No.5, (October 2000), pp. 984-993, ISSN 0278-0046.

[5] Bonaldi, E.L, de Oliviera, L.E.L., Lambert-Torres, G. & Borges da Silva, L.E. (2007).Proposing a Procedure for the Application of Motor Current Signature Analysis on Predictive Maintenance of Induction Motors, Proceedings of the 20th International Congress & Exhibition on Condition Monitoring and Diagnosis Monitoring Management - COMADEM 2007, Faro, Portugal, Jun. 13-15, 2007.

[6] Borges da Silva, L.E., Lambert-Torres, G., Santos, D.E., Bonaldi, E.L., de Oliveira, L.E.L. & Borges da Silva, J.G.(2009). An Application of MSCA on Predictive Maintenance of TermoPE's Induction Motors, Revista Ciências Exatas, Vol. 15, No. 2, (July 2009), pp. 100-108, ISSN 1516-2893.

[7] Thomson, W. T., "On-Line MCSA to Diagnose Shorted Turns in Low Voltage Stator Windings of 3-Phase Induction Motors Prior to Failure," Proceedings of IEEE Conference on Electrical Machines and Drives (IEMDC), Massachusetts Institute of Technology, Boston, Massachusetts, 2001.

[8] Hargis, C., Gaydon, B. G., and Kamish, K., "The Detection of Rotor Defects in Induction Motors," Proceedings of IEE EMDA Conference, London, England, pp. 216-220, 1982.

[9] Schoen, R.R., Habetler, T.G.,Kamram, F. & Bartheld, R.G. (1995). Motor Bearing Damage Detection Using Stator Current Monitoring, IEEE Transactions on Industrial Electronics, Vol.31, No.6, (Nov/Dec 1995), pp. 1274-1279, ISSN 0278-0046.

[10] Abhisek Ukila Shuo Chenb Andrea Andennaa, Electric Power Systems Research Detection of stator short circuit faults in three-phase induction motors using motor current zero crossing instants, Electric Power Systems Research 3205 (2010).

[11] Didier, G., Ternisien, E., Caspary, O., and Razik, H. (2007).A new approach to detect broken rotor bars in induction machines by current spectrum analysis Mechanical Systems and Signal Processing, vol. 21, no. 2, pp. 1127- 1142.

[12] Jung, J.H., Lee, J.J. and Kwon, B.H. (2006). On-line Diagnosis of Induction Motors Using MCSA. IEEE Transaction on Industrial Electronics, vol. 53, no. 6, pp. 1842-1852.

[13] Mehala, N., Dahiya, R. (2009). Condition monitoring methods, failure identification and analysis for Induction machines. International Journal of Circuits, Systems and Signal Processing, vol. 3, Issue 1, pp. 10-17.

[14] Çalis, H., and Çakir, A. (2007). Rotor bar fault diagnosis in three phase induction motors by monitoring fluctuations of motor current zero crossing instants. Electric Power System Research, vol. 77, no. 5-6, pp. 385-392.