International Journal of Electrical and Computer Engineering.
ISSN 0974-2190 Volume 8, Number 1 (2016), pp. 1-6

http://www.irphouse.com

Diagnosis of Mechanical Faults in Electric Motors

Neelam Turk
Department of Electronics and Comm. engineering
Y.M.C.A University of Science and Technology
Faridabad-121006 (Haryana), India.

Abstract

The ability to monitor the condition of an electrical machine has been a concern of industry for many years. Knowing when a machine requires maintenance allows users to perform the required maintenance at their convenience, rather than during costly unscheduled shutdowns. This need for improved industrial monitoring techniques has produced a number of studies on the detection of mechanical faults in induction machines.The condition monitoring of the electrical machines can significantly reduce the costs of maintenance by allowing the early detection of faults, which could be expensive to repair. In this paper, Mechanical faults of induction motor eccentricity faults are experimentally diagnosed with help of motor current signature analysis.

Introduction

Fault detection of electric machines and drive systems is a challenging task that has recently attracted increasing attention. An intelligent regime of online condition monitoring leading to fault identification, fault location, and fault-severity evaluation represents the far goal. Precise diagnosis and early detection of incipient faults help avoid harmful, sometimes devastative, consequences of the fault. Repair requirements and the time frame could be pre-set based on the automatic diagnostics, which reflects lower cost. There are many condition monitoring methods, including vibration monitoring, temperature monitoring, chemical monitoring, acoustic emission monitoring, current monitoring etc. [3]. Except for current monitoring, all these monitoring methods require expensive sensors or specialized tools and are usually intrusive. In current monitoring, no additional sensors are necessary. This is because the basic electrical quantities associated with electromechanical plants such as currents and voltages are readily measured by tapping into the existing voltage and current transformers that are always installed as part of the protection system. As a result, current monitoring is non-intrusive and may even be implemented in the motor control center remotely from the motors being monitored. Therefore, current monitoring offers significant implementation and economic benefits. Another advantage of current monitoring is that an overall electric machine condition monitoring package is possible, given the fact that the detection of other machine faults and the estimation of machine speed and efficiency have been well achieved via stator current. Thus, Current monitoring techniques are most effective for detecting faults of induction motor. But it is fact that very limited numbers of current monitoring techniques are used in the industry because it is very difficult to assess the severity of fault based on current signature [4]. In this paper, Mechanical fault such as eccentricity fault is diagnosed with help of Motor Current Signature Analysis. This is a feature extraction technique. The aim of feature extraction is to extract the signal features hidden in the original time domain.

Diagnosis of Eccentricity Fault

Air gap eccentricity may be detected by identifying the characteristics current signature pattern being indicative of abnormal levels of air gap eccentricity and to then that signature. Air-gap eccentricity in electrical machines can occur as static or dynamic eccentricity. The effects of air-gap eccentricity produce unique spectral patterns and can be identified in the current spectrum. The analysis is based on the rotating wave approach whereby the magnetic flux waves in the air-gap are taken as the product of permeance and magnetomotive force (MMF) waves. The frequency equation for determining air-gap characteristics is as follows [6,7,8]:

$$f_{ag} = \left\{ \left(n_{rt} R \pm n_d \right) \frac{(1-s)}{p} \pm n_{\omega s} \right\} f_1 \tag{2}$$

where

- f_{ag}= frequency components in a current spectrum due to rotor slotting and air gap eccentricity, Hz
- n_{rt}= any integer, 0, 1, 2, 3, ...*R* = number of rotor bars
- n_d= eccentricity order number; any integer, 0, 1, 2, 3, ...
- n_d= 0 for static eccentricity (principal slot harmonics)
- n_d= 1, 2, 3, ... for dynamic eccentricity
- s = nondimensional slip ratio
- p = pole-pairs, which is half the number of poles (P), i.e. $p = P/2$
- n_{ws}= order number of stator MMF time harmonic or stator current time harmonic; odd integer, 1, 3, 5, ...
- f_1= supply line frequency, Hz

In general, this equation can be used to predict the frequency content for the current signal. There are three *n*'s in the equation and, therefore, three sets of harmonics: n_{rt} is rotor related, n_{ws} stator related and n_d eccentricity related. For static eccentricity variations n_d= 0 and for dynamic eccentricity variations n_d= 1, 2, 3, ...

System Under Analysis

A system for fault detection was developed and implemented based on Motor Current Signature Analysis (MCSA). The stator current is first sampled in the time domain and in the sequence; the frequency spectrum is calculated and analyzed aiming to detect specific frequency components related to incipient faults. For each motor fault, there is an associated frequency that can be identified in the spectrum. The faults are detected comparing the amplitude of specific frequencies with that for the same machine considered as healthy. Based on the amplitude in dB, it is also possible to determine the degree of faulty condition. In the described system, data acquisition board was used to acquire the current samples from the motor operating under different load conditions. The current signals are then transformed to the frequency domain using a Fast Fourier Transform (FFT).

Detection of Air Gap Eccentricity Detection

This section of research paper is focused on air gap eccentricity faults. In practice, all three-phase induction motors contain inherent static and dynamic eccentricity. Air gap eccentricity causes a ripple torque, which further leads to speed pulsations, vibrations, acoustic noise, and even an abrasion between the stator and rotor. Therefore, it is critical to detect air gap eccentricity as early as possible. To replicate the eccentricity fault in laboratory, special methods were used. The effects of eccentricity faults under different load condition are studied to get the fault signature information.

Experimental Results

To detect the air gap eccentricity, the current was analyzed to identify the current components between the frequencies 750 Hz to 950 Hz. The slip was 0.01, and 0.08 at no load and full load respectively. Figure 1 shows a power spectrum between 900 Hz to 1000 Hz to accurately determine the frequency components for 25% static eccentricity at no load. Virtual Instrument (VI) predicted current components (941 Hz) due to abnormal level of static eccentricity for no load conditions. The results show that the components predicted by equations (2) are present. Figure 2 shows the current spectra from motor after its housing was machined and installed again with 50% air gap setting at no load. This figure shows the increased level of fault frequency at 941 Hz.

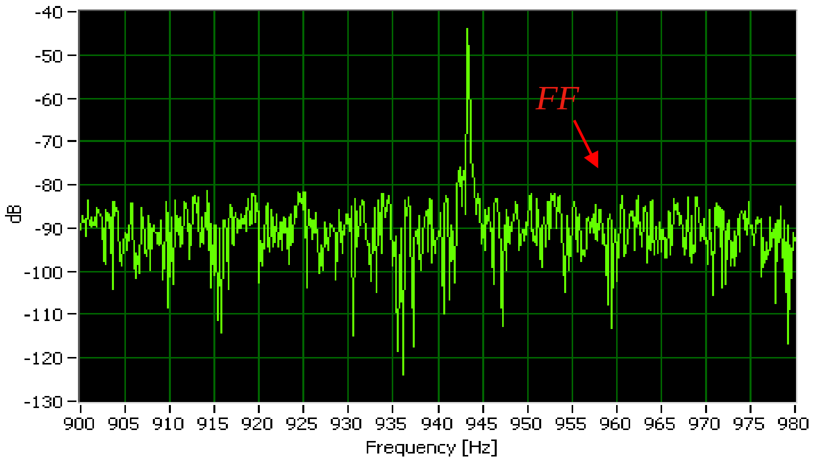

Figure 1: Power spectrum of faulty motor with 25% Static eccentricity under no load condition

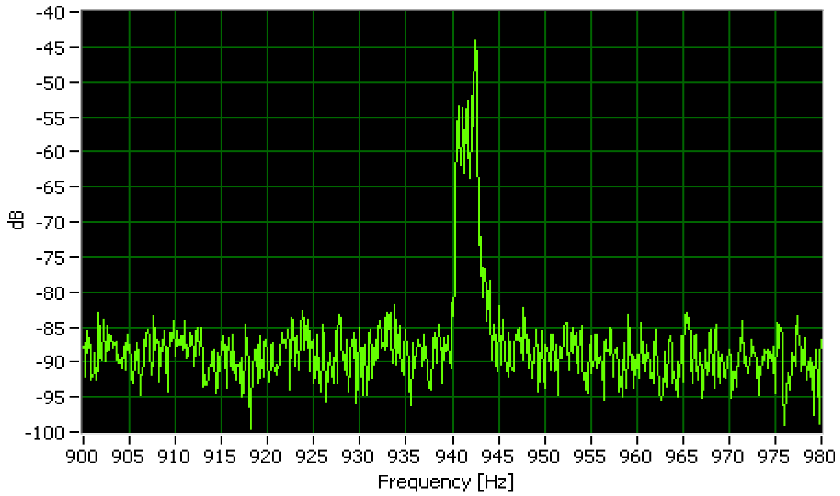

Figure 2: Power spectrum of faulty motor with 50% static eccentricity under no Load condition

Conclusion

The subject of on-line detection of air-gap eccentricity in three phase induction motor is discussed in this paper. Experimental results obtained by using a special fault producing test rig, demonstrate the effectiveness of the proposed technique, for detecting presence of air gap eccentricity in operating three phase induction machine. Experimental results show that it is possible to detect the presence of air-gap eccentricity in operating three phase induction motor, by computer aided monitoring of stator current. This can be concluded from the study that air gap eccentricity can be detected at low cost by current monitoring using FFT based power spectrum.

References

[1] P. J. Tavner and J. Penman, “Condition Monitoring of Electrical Machines. Hertfordshire”, England: *Research Studies Press Ltd,* ISBN: 0863800610, 1987.

[2] W. T. Thompson, “A review of on-line condition monitoring techniques for three phase squirrel induction motors – Past, present and future,” in *Proc. IEEE Int. Symp. Diagnostics Electrical Machines, Power Electronics Drives,* pp. 3–18, 1999.

[3] Peter Vas, “Parameter estimation, condition monitoring, and diagnosis of electrical machines”, Clarendon Press Oxford., 1993.

[4] A.H. Bonnett and G.C. Soukup, “Rotor failures in squirrel cage induction motors”, IEEE Trans. Ind. Application. . Vol. IA-22, pp 1165-1173, Nov. Dec. 1986.

[5] J. Sottile and J. L. Kohler, “An on-line method to detect incipient failure of turn insulation in random-wound motors,” *IEEE Trans. Energy Conversion,* vol. 8, no. 4, pp. 762-768, December, 1993.

[6] Jung J.H., Lee J.J., and Kwon B.H., “Online Diagnosis of induction motor using MCSA”, *IEEE transaction on industrial electronics,* Vol. 53, no. 6, pp. 1842-1852, Dec. 2008.

[7] W. T. Thomson, D. Rankin, and D. G. Dorrell, “On-line current monitoring to diagnose airgap 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.

[8] W. T. Thomson, D. Rankin, and D. G. Dorrell, “On-line current monitoring to diagnose airgap eccentricity-an industrial case history of a large high-voltage three-phase induction motors,” *Electric Machines and Drives Conference Record,* ppMA2/4.1-MA2/4.3, 1997.

[9] Benbouzid, M. E. H., “A Review of Induction Motors Signature Analysis as a Medium for Faults Detection”, *IEEE Transactions on Industrial Electronics,* Vol. 47, October, No. 5,pp. 984-993, 2000.

[10] Neelam Mehala, Ratna Dahiya , “Condition monitoring methods, failure identification and analysis for Induction machines”, *International Journal of Circuits Systems and Signal Processing,* Volume 3, Issue 1, pp. 29-35, 2009.

[11] Neelam Mehala, Ratna Dahiya, “Motor Current Signature Analysis and its Applications in Induction Motor Fault Diagnosis*”, International conference on Signal Processing, Robotics and Automation (ISPRA-08),* Cambridge, UK, Feb. 20-22, pp. 442-448, 2008

[12] Neelam Mehala, Ratna Dahiya, A Comparative Study of FFT, STFT and Wavelet Techniques for Induction Machine Fault Diagnostic Analysis, *International conference on computational intelligence, Man machine systems and cybernetics,*Cario, Egypt, Dec., 29-31, 2008, pp. 203-208, 2008.

[13] T.H. Loutas, D. Roulias, E. Pauly, V. Kostopoulos , “The combined use of vibration, acoustic emission and oil debris on-line monitoring towards a more effective condition monitoring of rotating machinery” *Mechanical Systems and Signal Processing*,Vol. 25, no.4, pp. 1339-1352, 2011.