DETECTION OF BROKEN ROTOR BAR FAULT IN THREE PHASE INDUCTION MOTOR USING LEAKAGE FLUX ANALYSIS

Ruchira Patole [1], Prof. Monika Bhagwat [2]
[1]ME Scholar: dept. of electronics engineering, [2]Professor: dept. of electronics engineering
Dr. K. M. Vasudevan Pillai College of Engg media studies and research, New Panvel, Maharashtra

Abstract
Induction motors have been used widely in numerous applications since several decades. There is always an ever increasing demand for dependable and safe operation of the induction motors. This gives the need for condition monitoring of the induction motors. In this paper, analysis performed on three phase induction motor for the detection of broken rotor bar fault is explained. An external search coil is used for the detection of faults
Index Terms: three phase induction motor, rotor bar, leakage flux, search coil.

I. INTRODUCTION

The constant need to decrease the functional and maintenance cost has increased the significance of condition monitoring of electrical machinery. At present, the induction motors are the critical components to be supervised and monitored as they play a fundamental role in all the engineering processes. To this aim, it is important to provide induction machines with advanced condition monitoring systems which can take the measurements while the machine is operating. This will help to avoid undesirable conditions and to detect incipient faults.

II. BROKEN ROTOR BAR FAULT

The literature review done on the detection of broken rotor bar faults in an induction motor reveals that, those researches involving the study of voltages induced in external search coils prove to be the most useful and cost effective fault diagnosing technique. An external search coil held against the casing of the motor has the same potential as that of an internal search coil mounted on a stator tooth in order to detect a fault related to rotor. The characteristic frequencies at which the rotor fault would become distinguishable are given by:

$$f_{brb} = f_s\left[\left(\frac{k}{p}\right)(1-s) \pm s\right] \quad \text{....Equation 1}$$

or

$$f_{brb} = s.f_s = f_s(2s \pm 1) \quad \text{....Equation 2}$$

Techniques relying on the indications provided by internally mounted search coils proved to sense well enough rotor faults such as broken damper bars [10].

The axial leakage flux obtained by placing an external search coil around the shaft of the motor can also detect the rotor bar faults when analyzed in the frequency domain.

III. LEAKAGE FLUX ANALYSIS

Of the total flux generated by the machine, all the flux is never useful; the amount of flux that crosses the air gap to electromagnetically link the stator and the rotor can be called as the main flux and the remaining is the leakage flux which does not cross the air gap. These leakage fluxes however produce harmonic components of the air gap flux which are detrimental and lead to the failure of the machine. Leakage flux also adds extra losses by deteriorating the frame of the machine, considerably increasing the copper losses of the stator and rising the conductor slot skin effect. Also, there is some leakage flux in the air gap as well, even though it crosses the air gap it does not participate in the stator rotor linkage process.

IV. EXPERIMENTAL SETUP

A. Test motor specifications

Two test motors of the same specifications and manufacturer are used. The specifications of the motors under are as follows:

Table 6.1. Specifications of the test motor

Rated power	0.5 Hp
Rated frequency	50 Hz
Rated voltage	415 V
Rated Current	0.8 A
Stator connection	Star
RPM	700

Two test motors of the same specifications are used so that the readings in both the cases, i.e.; healthy and faulty; can be obtained and faults can be diagnosed by comparing the readings. The test motors have been analyzed from the manufacturing process to avoid any kind of imperfections so that accurate readings can be obtained. The amount of leakage flux that is present in both the four motors in healthy condition is also acquired.

B. Artificially inducing broken rotor bar fault

Broken rotor bar fault is induced by drilling holes in the rotor as shown in figure 1 and 2. This fault can lead to a serious damage in the motor as every crack, hole or fracture in the bar will eventually break the entire bar, this broken bar will cause an increase in current in all the other bars which as a consequence will come out of the slot damaging the stator winding.

Figure 1. Drilling holes in the rotor

Figure 2. Artificially induced broken rotor bar fault

Figure 3. The search coil used for detecting the faults

This search coil produces output voltage proportional to the amount of leakage flux encountered. After introducing fault, we have a healthy motor and a faulty motor with broken rotor bar fault, leakage flux is detected using the search coil for both the motors. The healthy motor produces very less amount of leakage flux as compared to the faulty motor. After obtaining the output signal from the search coil for both the cases; the signal is amplified and filtered to perform Fast Fourier Transform converting the time domain signal to frequency domain signal.

V. RESULTS

This section shows, the time domain and frequency domain representation of the voltages induced in the search coil for broken rotor fault in the motor.

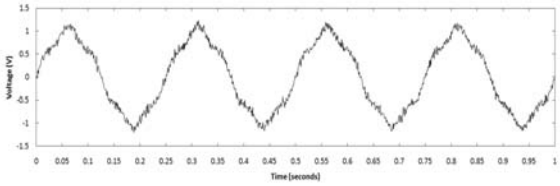

Figure 3. Voltage induced in the search coil when placed near the non drive end in the presence of broken rotor bar fault (time domain)

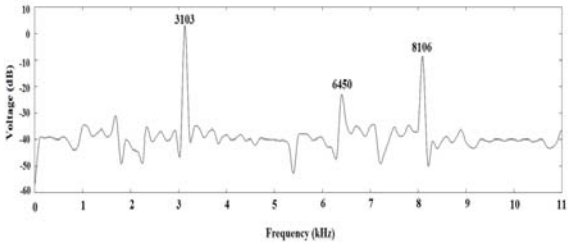

Figure 4. Voltage induced in the search coil when placed near the non drive end in the presence of broken rotor bar fault (frequency domain)

Fig. 3, 4 show the flux signatures obtained when the search coil is held near the ventilator. The frequency spectrum points out the characteristic frequency components (at 3103 Hz, 6450 Hz, 8106 Hz) produced by the rotor faults in the indications provided by the search

coil. The frequencies obtained are similar to those obtained theoretically. Thus, it provides potential information about the fault.

Theoretical value of frequencies (Hz)	Practical value of frequencies (Hz)
3087	3103
6435	6450
8084	8106

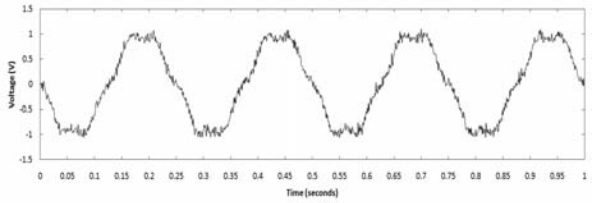

Figure 5. Voltage induced in the search coil when placed near the non drive end (at a distance of 10cm) in the presence of broken rotor bar fault (time domain)

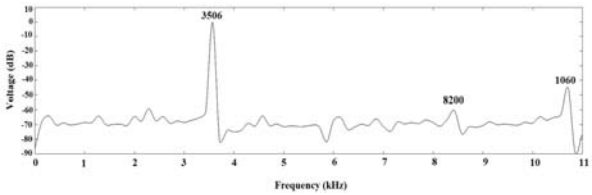

Figure 6. Voltage induced in the search coil when placed near the non drive end (at a distance of 10cm) in the presence of broken rotor bar fault (frequency domain)

When the coil is held at some distance away from the non drive end of the motor the voltage spectrum continues showing the characteristic frequencies but with minor changes in the values.

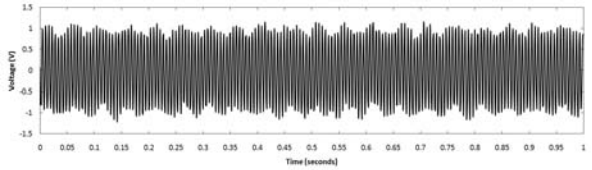

Figure 7. Voltage induced in the search coil when placed around the shaft in the presence of broken rotor bar fault (time domain)

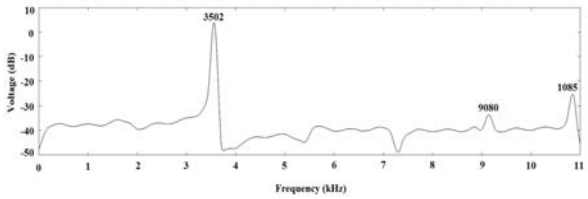

Figure 8. Voltage induced in the search coil when placed around the shaft in the presence of broken rotor bar fault (frequency domain)

When the search coil is held around the shaft, the frequency components provided by the signals represent the presence of rotor fault but, the readings lack precision as seen in fig. 7, 8.

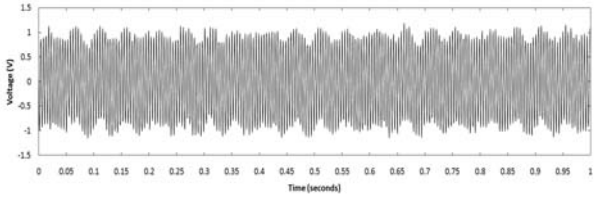

Figure 9. Voltage induced in the search coil when placed 180 degrees electrical in the presence of broken rotor bar fault (time domain)

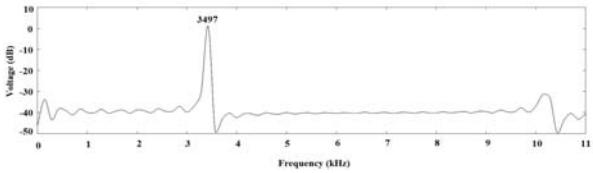

Figure 10. Voltage induced in the search coil when placed 180 degrees electrical in the presence of broken rotor bar fault (frequency domain)

When the search coil is held in parallel with the motor, the frequency components provided by the signals represent the presence of rotor fault but, the deficiency of number of readings provided make it less useful.

VI. CONCLUSION

The leakage flux analysis performed in this project provided valuable information about the faults under study in a three phase induction motor. Rotor fault (broken rotor bar) is conveniently diagnosed by monitoring the leakage flux in parallel to the motor. The copiousness of the details provided by the frequency spectrum of the signal acquired from the search coil uncomplicatedly detects the fault.

REFERENCES

[1] M.L. Sin, W.L. Soong and N. Ertugrul, "Induction machine on-line condition monitoring and fault diagnosis – a survey", *University of Adelaide,2013.*

[2] A. Negoiţă, Gh. Scutaru, R.M. Ionescu, "A brief review of monitoring techniques for rotating electrical machines", *Bulletin of the Tran2 University of Braşov, Vol. 3 (52) – 2010*.

[3] K. L . Shi, T. F. Chan, Y. K. Wong and S. L . Ho, "Modelling and simulation of the three-phase induction motor using simulink", *Int. J. Elect. Enging. Educ., Vol. 36, pp. 163–172. Manchester U.P., 1999.*

[4] V. Fernão Pires1, Tito G. Amaral1, J. F. Martins, "Stator Winding Fault Diagnosis in Induction Motors using the dq Current Trajectory Mass Center" , *IEEE transactions on Industrial Electronics, VOL. 46-49, NO. 369, JUNE 2009*.

[5] Randy Supangat, Nesimi Ertugrul, Wen L. Soong, Douglas A. Gray, Colin Hansen and Jason Grieger, University of Adelaide School of Electrical and Electronic Engineering Adelaide, Australia, "Broken Rotor Bar Fault Detection in Induction Motors Using Starting Current Analysis".

[6] Marian Dumitru Negrea, "Electromagnetic flux monitoring for detecting faults in electrical machines", *Doctoral Dissertation, Helsinki University of Technology Department of Electrical and Communications Engineering Laboratory of Electromechanics*

[7] Mounir Djeddi, Pierre Granjon, Benoˆıt Leprettre. "Bearing Fault Diagnosis in Induction Machine Based on Current Analysis using High-Resolution Technique". *The 6th IEEE International Symposium on Diagnostics for Electric Machines, Power Electronics and Drives, Sep 2007*, Cracovie, Poland. <hal-00186819>

[8] Masahiro Ikeda and Takashi Hiyama, Senior Member, IEEE, " Simulation Studies of the Transients of Squirrel-Cage Induction Motors", *IEEE transactions on energy conversion, vol. 22, no. 2, June 2007.*

[9] Mohammed Obaid Mustafa, George Nikolakopoulos, Thomas Gustafsson, Department of Computer Science, Electrical and Space Engineering Luldl University of Technology, "A Fault Diagnosis Scheme for Three Phase Induction Motors based on Uncertainty Bounds", *IEEE Transactions on Energy Conversion, vol. 20, no. 4, pp. 719-729, Dec. 2013.*

[10] A. Yazidi, H. Henao, G. A. Capolino, M. Artioli, F. Filippetti, D. Casadei, "Flux Signature Analysis: an Alternative Method for the Fault Diagnosis of Induction Machines", *IEEE Trans. Ind. Applicat., vol. 40,*