International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization on TPE (IOTPE)

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

December 2010	Issue 5	Volume 2	Number 4	Pages 69-73

STUDY RELATION BETWEEN FAULT NOISE IN ELECTRIC MOTOR

M. Iorgulescu

Electrical Engineering Department, University of Pitesti, Pitesti, Romania, iorgulescumariana@mail.com

Abstract- In this paper, the noise of electric motors is analyzed in order to obtain information for the detection of faults. Significant noise spectrum differences between healthy motor and motors with different faults are observed. The faults analyzed are bad bearing in the three phase induction motor and broken bars in single phase induction motor. The high-frequency spectral analysis of noise provides a method to detect faults.

Keyword: Diagnosis, Electric Motor, Faults.

I. INTRODUCTION

The induction machines are widely used for their simplicity, robustness and their low cost. Because of this, research has been made since long ago to detect a fault that occurs in electrical machines. Furthermore, these machines can be subjected to different operating conditions that can produce electrical or mechanical damages on the stator and/or the rotor and bearings too. It is well known that the bearing faults constitute a significant part of the faults of the induction motors. This is why research on the faults of these electrical machines has developed many techniques based on the signals analysis applied to measure parameters such as vibrations, noise the magnetic flux, power, voltage or stator current. In this paper, we use vibration and noise analysis method to detect the bearing faults [1]. This technique is based on the spectral analysis of noise signals.

The method allows off-line fault detection. However, on-line methods exist and contribute to limiting the problems and the cost induced by the failure of a motor in an industrial process. In this study, we take into consideration the electric and mechanical faults. This type of faults reveals in the noise spectrum some sidebands, which have specific frequencies. It is known the fact that induction motor parameters will change because of the motors' faults**.** That's why these parameters have to be monitored and, in order to prevent breakdowns.

The human being directly perceives only a small range of low frequency vibrations. The oscillation velocity is turning the vibration into noise. The growth of air pressure is proportional to the velocity of the oscillating surface. That is why the standards generally limit the oscillation velocity of electrical machines. This also limits the noise**.**

Noise analysis is a remote, not-intrusive way to test the electrical machine being monitored. It is based on the analysis of the noise waveform using complex mathematics. Electrical machines have mechanical parts that oscillate. These oscillations are transmitted to external system coupled with the machine shaft. This results in a machine-related frequency spectrum that characterizes healthy machine behavior.

When mechanical part of the motor either wears or breaks up, a frequency component of the spectrum will change. In fact, each fault in a rotating machine produces vibrations and noise with distinctive characteristics that can be measured and compared with reference ones in order to perform the fault detection and diagnosis.

It is known that mechanical problems can cause a motor to seem to have significant electrical problems when being evaluated without vibration analysis. As an example a severely misalign shaft can create a variable air gap between stator and rotor. Therefore it is a good method to make a detailed motor noise analysis.

Noise monitoring system requires storing of a large amount of data. Noise is often measured with sensors mounted near of the machine. For each machine there are several typical noise signals being analyzed in addition to some static parameters like load [1], [2].

II. NOISE ANALYSIS

A. Mechanical Problems in Induction Motors

A great number of mechanical problems can be detected by using noise monitoring. The classical mechanical problems in induction motors are the following [3]:

- Bearing wear and failure. As a result of bearing wear, air gap eccentricity can increase**,** and this can generate serious stator core damage and even destroy the winding of the stator**;**
- High mechanical unbalance in the rotor increases centrifugal forces on the rotor;
- Looseness or decreased stiffness in the bearing pedestals can increase the forces on the rotor;
- Critical speed shaft resonance increases forces and vibration on the rotor core.

B. Noise Diagnostics

For the noise diagnostics the sound quality and the noise source are analyzed.

The noise is measured using a microphone. The noise signals are converted in electric signals. It is necessary to analyze this signal without losing the diagnostic information. There are very strict requirements for the analyzing instruments. The operations that the noise analyzing instruments must perform are the following:

- Measurement of overall noise level in a standard frequency range and using the units required by these standards.
- Spectral analysis of the noise, by using FFT.

III. INDUCTION MOTOR FAULT

The major faults of induction motors can broadly be classified as the following:

- Bearing wear and failure. As a result of bearing wear, air gap eccentricity can increase**,** and this can generate serious stator core damage and even destroy the winding of the stator;
- Stator faults resulting in the opening or shorting of one or more of a stator phase windings,
    - Abnormal connection of the stator windings,
    - Static and/or dynamic air-gap irregularities.
- High mechanical unbalance in the rotor increases centrifugal forces on the rotor;
- Broken rotor bar or cracked rotor end rings
- Looseness or decreased stiffness in the bearing pedestals can increase the forces on the rotor;
- Critical speed shaft resonance increases forces and vibration on the rotor core.
- Bent shaft which can result in a rub between the rotor and stator, causing serious damage to stator core and windings [4], [5], [6], [7].

The three phase induction motor noises are measured to detect bearing faults. In the single phase motor case the fault detects is a broken bars rotor.

A. Techniques for Monitoring Bearing Faults

The analysis of the bearing noise in electrical machines shows that the forces that occur in the rolling element bearings create the high frequency components of vibrations. In normally working rolling element bearings, the main types of high frequency oscillating forces are friction forces. When a defect develops in the bearing, shock pulses can also be found due to the breaks in the lubrication layer between the friction surfaces.

This method of diagnosing rolling element bearings through analysis of high frequency noise has many advantages. It makes it possible to locate the defective bearing easier because the noise signal does not contain any components from other units of the machine.

When a defect of wear of rolling surfaces appears, the friction forces are not uniform. They depend on the rotation angle of the rotating surfaces in the bearing causing the friction forces to be modulated by a periodic process. Periodic shock pulses appear if cavities or cracks appear in the bearing. It is possible to detect the presence of the friction forces modulation and of the periodic shock pulses by the spectral analysis of the envelope of the random noise produced by these processes. When the friction forces are modulated by a periodic process the harmonic component of the frequency will be found in the measured envelope spectrum. The frequency is determined by the period of the modulating process.

B. Monitoring Bearing Faults in Induction Motor Using Noise Spectrum

The techniques used to detect the presence of bearings failure are [2]:

- vibration spectrum
- noise spectrum
- monitored stator current - rms value
- monitored stator current spectrum

The analysis of noise spectrum is used for the detection of bearing faults. The faults detection will be done by comparing two values: the amplitudes of the harmonic components obtained from monitoring the noise spectrum at different frequencies and the amplitudes of the harmonic components at the same frequencies obtained from the reference spectrum.

IV. THE NOISE SIGNATURE OF THREE PHASE INDUCTION MOTOR

The motor tested in this paper is a three phase induction motor, with the following parameters:

- rated voltage 130V,
- rated power 0.75kW,
- rated current 1.57A,
- rated slip 4.00%,
- efficiency 78%.

The induction motor is equipped with 6202 ball bearing type having the number of balls N=8. Harmonic spectra are generated from collected data by the microphone using FFT. The Fourier fast transform (FFT) is a mathematical operation that is used to extract from a time-domain signal the frequency domain signal representation.

The harmonic spectrum from Figure 2 is generated from data obtained by the microphone. Initially the measurements were realised by using electric motor with "healthy" bearing. Then we made the measurement by the same motor with damage bearing. The harmonic spectrum from Figures 1 and 2 is generated from data obtained by the microphone. The rotational frequency is f=50Hz. The noise amplitude for this frequency is important and the amplitudes for other frequencies are small.

The analyzed frequencies are multiples of 50 Hz . The noise amplitude for the analyzed frequencies, for the induction motor with bearing fault are bigger than for the same motor with healthy bearing. It is very important to analyzed noise amplitude because difference greater than 10% will be an indication of bearing problems.

In Figure 3 we make this analysis, and an increase of the noise amplitudes in the bearing. The noise analysis is very useful for induction motor manufactures in bearing fault diagnosis.

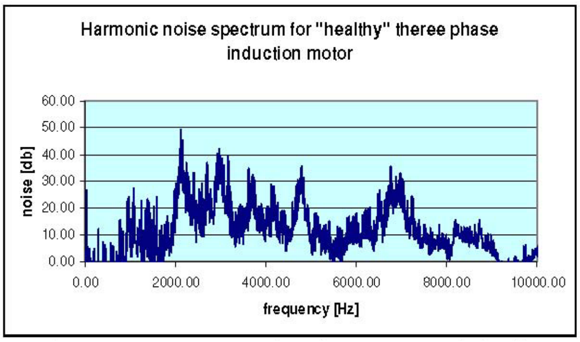

Figure 1. Harmonic noise spectrum for induction motor with “health”

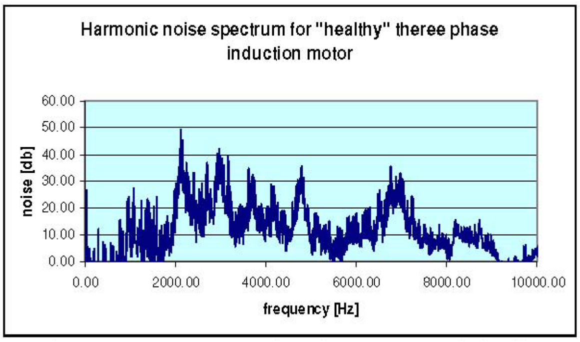

Figure 2. Harmonic noise spectrum for induction motor with “bad” bearing

In Figures 1 and 2 we present the harmonic noise spectrums for the induction motor with “healthy” bearing and fault bearing.

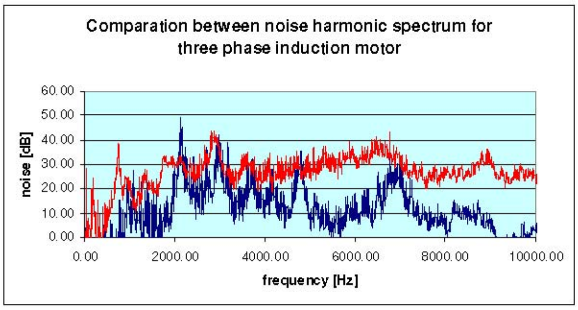

Figure 3. Comparison between harmonic noise spectrums for “healthy” and bad bearing

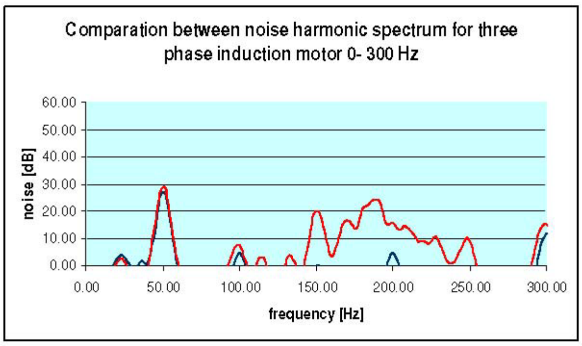

Figure 4. Comparison between noise spectra “healthy” and bad bearing fault in 0-300 Hz frequency range

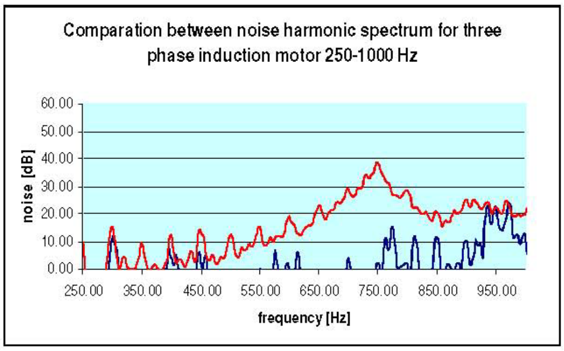

Figure 5. Comparison between noise spectra “healthy” and bearing fault in 250-1000 Hz frequency range

By comparing (Figure 3) the harmonic spectrum obtained we observe that the noise level depends obviously on the state of the bearing**.**

For the relevant conclusions it is need to make a zoom in for the frequencies range 0-1000 Hz. So it is obtained the spectrum that in Figures 4 and 5. We observe that the noise amplitudes are increased in the fault motor.

V. THE NOISE SIGNATURE A SINGLE PHASE INDUCTION MOTOR

The motor tested in this paper is a single phase motor, with the following parameters:

- rated voltage 230 V,
- rated power 0.75kW,
- rated current 1.57A.

The experiment has target to single induction motor diagnosis, more precisely rotor fault using noise measurement. Initially the measurements were realised by using electric motor with “healthy” rotor. Then we made the measurement successive by the same motor with a broken rotor bar, with two broken bars and three broken rotor bar, with two broken bars and three broken bars.

The harmonic noise spectrum from Figures 6, 7, 8 and 9 is generated from data obtained by the microphone. The noise amplitude for the analyzed frequencies, for the induction motor with rotor fault (broken bars) are bigger than for the same motor without rotor fault.

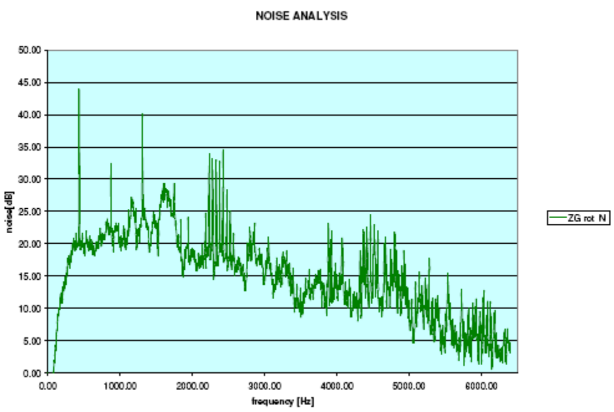

Figure 6. Harmonic vibration spectrum for “healthy” single induction motor

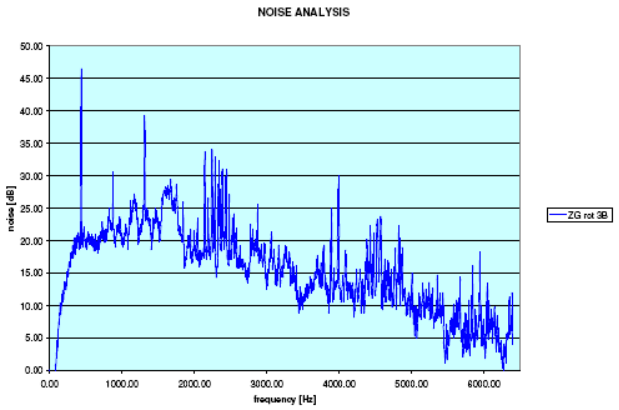

Figure 7. Harmonic vibration spectrum for induction motor with two broken bars

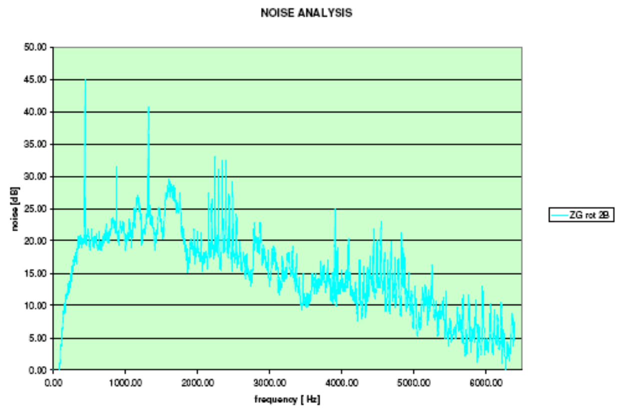

Figure 8. Harmonic vibration spectrum for induction motor with three broken bars

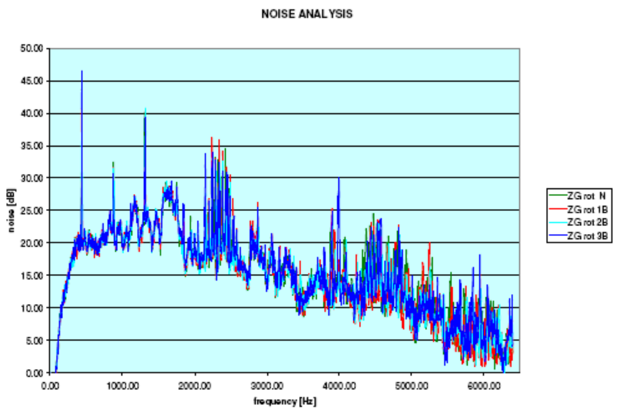

Figure 9. Comparison between harmonic variation spectra for healthy and fault rotor bars

We make this analysis, and observe an increasing of the vibration amplitude in the defective rotor. For the relevant conclusions it is need to make a zoom in for the frequencies range 400-450 Hz and 2100-2200 Hz. So it is obtained the spectrum that in Figures 10 and 11.

For the dynamic unbalanced frequency of motor, more precisely 440 Hz is important to follow the noise evolution from the healthy rotor (balanced) to one broken bar rotor, then two broken bars and three broken bars. We observe that the noise according to motor with three broken bars it is bigger than motor with two broken bars.

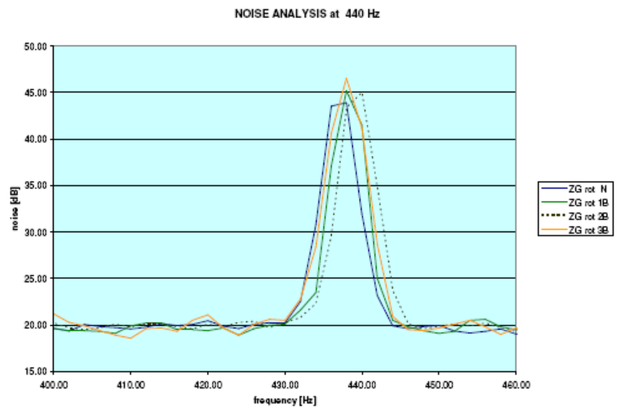

Figure 10. Comparison between vibration spectra "healthy" and rotor bars fault at 450 Hz frequency

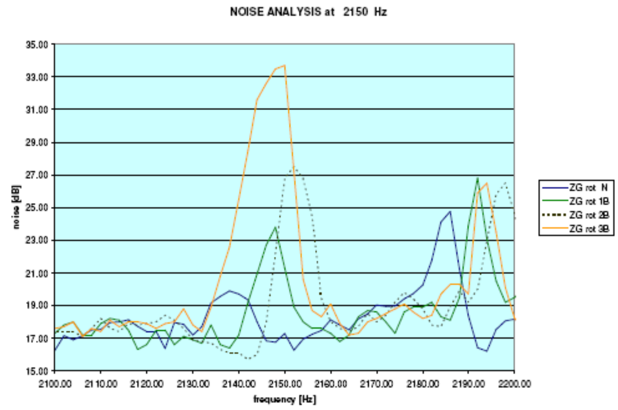

Figure 11. Comparison between vibration spectra "healthy" and rotor bars fault at 2150 Hz frequency

VI. CONCLUSIONS

The technique of evaluating the motor condition by performing a FFT of the induction motor noise has been verified by the experimental results. In this case electric motor noise motorizing is very useful to detect electric motor fault. It is demonstrated that the method of noise signature is efficient to make electrical motor diagnosis.

In this way, the plant maintenance can successfully detect mechanical and electrical fault that lead to unexpected downtime. A diagnostic procedure using a neural network shall be designed to detect any fault may come out.

REFERENCES

[1] W. Thomson and P. Orpin, "Current and Vibration Monitoring for Fault Diagnosis and Root Cause Analysis of Induction Motor Drives", Proceeding of the Thirty First Turbomachinery Symphosionum, pp. 61-68, 2002.
[2] J.A. Katsigiannis1, P.S. Georgilakis, A.T. Souflaris and K.P. Valavanis, "Diagnosing Transformer Faults with Petri Nets"
[3] P. Vas, "Artificial Intelligence Based Electrical Machines and Drives", Oxford University Press, 1999.
[4] G. Didier, H. Razik, A. Abed and A. Rezzog, "On Space Harmonics Model of a Three Phase Squirrel Cage Induction Motor for Diagnosis Purpose", EEP-PEMC, Dubrovnik, 2002.

[5] H. Toliyat and S. Nandi, "Condition Monitoring and Fault Diagnosis of Electrical Machines", IEEE, 1999.
[6] D.F. Pires, V.F. Pires, J.F. Martins and A.J. Pires, "Rotor Cage Fault Diagnosis in Three-Phase Induction Motors Based on a Current and Virtual Flux Approach", Energy Conversion and Management, 50, pp. 1026-1032, 2009.
[7] S. Nandi and H.A. Tolyat, "Detection of Rotor Slot and other Exccentricity Related Harmonics in a Three Phase Induction Motor with Different Rotor Cages", IEEE, 1998.
[8] P. Vas, "Parameter Estimation, Condition Monitoring, and Diagnosis of Electrical Machines", Clarendron Press, Oxford, 1993.
[9] F. Filippeti, G. Franceschini, C. Tassoni and P. Vas, "Broken Bar Detection in Induction Machines: Comparison Between Current Spectrum Approach and Parameter Estimation Approach", IEEE, 1994.

BIOGRAPHY

Mariana Iorgulescu was born in 1966. She received the B.S. and Ph.D. degrees from Faculty of Electrical Engineering of University Politehnica of Bucharest, Bucharest, Romania, in 1989 and 2006 respectively. She has been with the Electrical Engineering Department of University of Pitesti, Pitesti, Romania since 2002, where she worked as a lecturer. She's currently research preoccupations include diagnosis of electrical machines and expert systems. She is author or coauthor of 17 papers published in national and international journals or conference proceedings and 2 books.