FAULT DETECTION ALGORITHM FOR CONDITION MONITORING OF SQUIRREL-CAGE INDUCTION MACHINES

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ABSTRACT

The maintenance of electric machines is essential to their efficient and safe operation in any industry. The lack of an effectively designed and implemented maintenance policy will result in increased downtime, increased capital losses from catastrophic failures and decreased personnel safety. Therefore any new results in this field could be of real interest for all the specialists involved.

In this paper a simple condition monitoring algorithm will be described, which can be used in advanced condition monitoring systems in industrial environment. It can be used in both off-line and on-line monitoring systems.

INTRODUCTION

Condition monitoring and diagnosis are very important issues in electrical machine protection, because they can greatly improve the reliability, availability and maintainability in a wide range of applications. Furthermore, the addition of condition monitoring functions to existing systems need to be inexpensive or complicated, since using the existing sensors and hardware components can provide a vast array of motor and load information, which is not totally used.

The stator current monitoring method for incipient fault detection in induction machines is widely used for some time [1, 2, 3].

Current monitoring offers many advantages over conventional vibration monitoring [4]:

- No additional, potentially unreliable, sensors are necessary, above those current sensors already used for motor protection;
- Electrical faults, such as broken rotor bars, rotor unbalances, bearing faults and stator winding faults can be observed; and driven load conditions can be determined.

All of these advantages have made the area of stator current monitoring explode in the past few years [5, [6]. In this trend fits also the results obtained by our joint research Romanian-Hungarian research group

Based on the long time practical and theoretical experience in fault detection an easy to implement and use fault detection algorithm was established to be used in the condition monitoring of the squirrel-cage induction motors, very widely used in industry all around the world.

THE MOTOR CURRENT SIGNATURE ANALYSIS

As it was already stated out, one of the most frequently used fault detection methods is the motor current signature analysis (MCSA). This technique depends upon locating by spectrum analysis specific harmonic components in the line current produced of unique rotating flux components caused by faults such as broken rotor bars, air-gap eccentricity and shorted turns in stator windings, etc.

As an advantage of the method it should be mentioned that only a single current transducer is required for this method. Using the method all the above mentioned machine faults can be detected at an early stage, and thus secondary damage and complete failure of the motor can be avoided. Another advantage of this method is that it can be also applied on-line.

An idealised current spectrum is shown in Fig. 1. The two slip frequency sidebands due to broken rotor bars near the main harmonic can be clearly observed [5].

The fundamental reason for the appearance of the above-mentioned sideband frequencies in the power spectrum were presented in details in [7].

The classical twice slip frequency sidebands occur at $\pm 2sf_1$ around the supply frequency:

$$f_b = (1 \pm 2s)f_1 \tag{1}$$

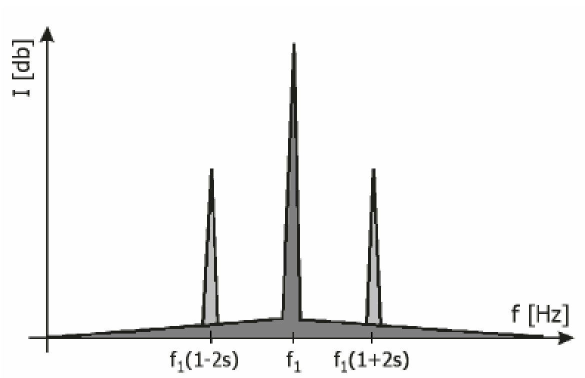

Fig. 1 Idealised current spectrum

While the lower sideband is specifically due to broken bar, the upper sideband is due to consequent speed oscillation. In fact, several papers show that broken bars actually give rise to a sequence of such sidebands given by:

$$f_b = (1 \pm 2ks)f_1, \quad k = 1, 2, 3 \ldots \tag{2}$$

Therefore the appearance in the harmonic spectrum of the sidebands frequency components given by (1) or (2) clearly indicates a rotor fault of the induction machine.

The motor current signature analysis method is based on the following assumptions:

- The speed of the machine is constant and known.
- The stator fundamental frequency is constant.
- The load is constant.
- The machine is sufficiently loaded in order to separate the sidebands from the fundamental.

Hence the sideband frequencies given by (1) or (2) are identified since the slip is known and assumed to be constant. A preset threshold has to be compared to the amplitudes of the sideband components having the computed frequencies.

THE DETECTION ALGORITHM

The proposed detection algorithm lies on the basis of the current signature method. Three sets of inputs are required: the measured phase current values, the measured speed of the motor and the threshold values for each possible motor fault.

First the sideband components corresponding to each fault type must be computed from the slip. Next the FFT must be performed for the measured current signal in order to obtain its spectrum. From this the amplitudes of the harmonic components having the computed sideband frequencies must be computed and compared with the corresponding preset thresholds. If an amplitude is greater than the threshold a fault signal is given.

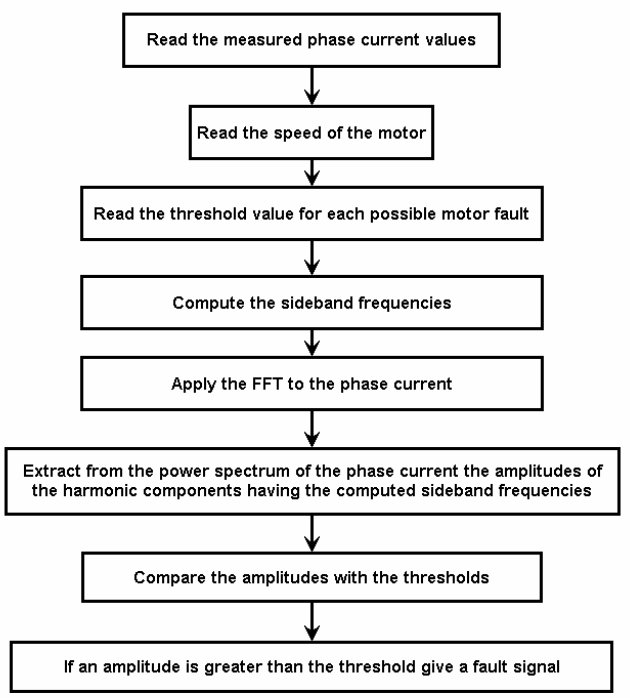

Fig. 2. The block scheme of the proposed monitoring algorithm

To test the theoretical background of the algorithm an advanced testbench was set up at the Electrical Machines Laboratory of the Technical University of Cluj, Romania [8].

Measurements had been performed with a healthy squirrel-cage induction machine, and with the same machine having 3, respectively 5 broken rotor bars [9]. The threshold for the rotor faults of this induction machine was set at 0.045 A.

As it can be seen from the spectrums of the phase currents given in Fig. 3 in the case of the motors with rotor faults the sideband components of the current spectrum having the frequencies computed with equation (1) have amplitudes that exceed the preset threshold. Hence in both cases the proposed condition monitoring algorithm should give a fault signal.

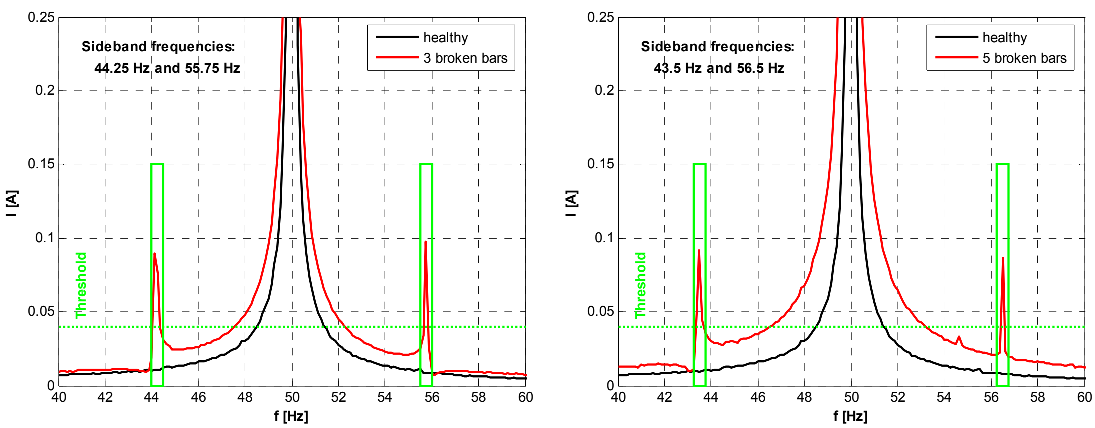

Fig. 3. The results of the measurements

CONCLUSIONS

The presented condition monitoring algorithms was proved by measurements to be useful in any plant where squirrel-cage induction motors run.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Nandi, S., Toliyat, H.A., "**Condition Monitoring and Fault Diagnosis of Electrical Machines – A Review**," Proceedings of the IEEE-IEMDC '99 Conference, Seattle, 1999, pp. 219-221.

[2] Szabó, L., Dobai, J.B., Biró, K.Á., "**Rotor faults detection in squirrel-cage induction motors by current signature analysis**," Proceedings of 2004 IEEE-TTTC International Conference on Automation, Quality and Testing, Robotics, Cluj (Romania), 2004, pp 353-358.

[3] Milimonfared, J. et al., "**A Novel Approach for Broken Rotor Bar Detection in Cage Induction Motors**," IEEE Transactions on Industry Applications, vol. 35 (1999), no. 5, pp. 1000-1006.

[4] Váradiné Szarka Angéla, "**Condition Monitoring of Electrical Drives in Mechatronic Systems**," Proceedings of the 3rd International Workshop on Mechatronic Courses, Miskolc (Hungary), 1997, pp.129-134.

[5] Thomson, W.T., Gilmore, R.J., "**Motor Current Signature Analysis to Detect Faults in Induction Motor Drives – Fundamentals, Data Interpretation, and Industrial Case Histories**," in Proceedings of 32nd Turbomachinery Symposium, A&M University, Texas, (USA), 2003.

[6] Szabó, L., Bíró, K.Á., Dobai, J.B., "**On the Rotor Bar Faults Detection in Induction Machines**," Proceedings of the International Scientific Conference MicroCAD '2003, Miskolc (Hungary), Section J (Electrotehnics and Electronics), pp. 81-86.

[7] Szabó L., Bíró K.Á., Fodor D., Kovács E., "**Improved Condition Monitoring System for Induction Machines Using a Model-Based Fault Detection Approach**," Oradea University Annals, Electrotechnical Fascicle, Computer Science and Control Systems Session, 2006, pp. 126-131.

[8] Szabó L., Kovács E., Bíró K.Á., Dobai J.B., Blága Cs., "**Advanced data acquisition systems used in the condition monitoring and diagnosis devices of electrical machines**," (in Hungarian), Proceedings of the ENELKO '2006 Conference, Cluj (Romania), 2006, pp. 117-121.