ANALYSIS OF THE CORRELATION BETWEEN VIBRATIONS AND THE NUMBER OF SHORTED TURNS IN THE STATOR WINDING OF A SQUIRREL-CAGE INDUCTION MOTOR

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MIKOŁAJ MARCZAK, WOJCIECH PIETROWSKI,
KONRAD GÓRNY

Poznan University of Technology, Institute of Industrial Electrical Engineering, Poznań, Poland
mikolaj.marczak@doctorate.put.poznan.pl, wojciech.pietrowski@put.poznan.pl, konrad.gorny@put.poznan.pl

This paper presents a method for diagnosing a squirrel cage induction machine based on machine vibration analysis. The study focuses on the consideration of a winding fault in the stator winding of an induction machine. The case of a winding fault in one phase was considered. The machine vibration signal was recorded at a constant load torque. Wavelet packet decomposition was used to analyse the recorded vibration signals. The results of the wavelet analysis were correlated with the number of shorted windings. The result was a method for detecting faults in an electrical circuit using the vibration signal.

Keywords:
diagnosing,
squirrel cage induction machine,
vibration analysis,
winding fault,
wavelet packet decomposition

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I Introduction

The planet's dwindling natural resources, which are vital to industry, are one of the reasons why increasing attention is being paid to extending the life of machinery. An important aspect of this is to take advantage of technological advances that can make a significant contribution to reducing production costs and improving operational efficiency. This is closely related to the issue of equipment diagnostics.

Induction machines are one of the most widely used pieces of industrial equipment and are used in virtually every industry, including driving production belts, fans and compressors. One of the most common faults in induction machines is coil shorts in the stator winding. This article focuses on single-phase shorts because they are relatively difficult to detect. Its occurrence can rapidly accelerate the deterioration of the machine and lead to subsequent failures. One of the many diagnostic methods for induction machines is the vibration-acoustic method, which uses a vibration signal. This method is characterised by, among other things, its non-invasiveness, which is manifested in the lack of need to immobilise the machine during diagnosis and the simplicity of connecting the measurement system. In this article, wavelet packet decomposition was used to analyse the waveform of the vibration signal. The results of the wavelet analysis were correlated with the number of short circuits.

II Measurement

A measurement system was designed and built to record machine vibration waveforms. A SVANTEK SV150 triaxial accelerometer with a 958A instrument acting as a signal amplifier was used to record and archive the vibration waveforms of the induction motor. A Celma Inducta 3SIE100L4B squirrel cage induction motor was selected for testing. The machine was prepared for inter-turn short-circuit testing by routing selected coil wires outside the machine housing. The diagram of the measurement system is shown in Figure 1.

The National Instruments CompactDAQ housing, equipped with a set of measurement cards, was used to record the waveforms. The manufacturer's DAQ Express software was used to manage the measurement configuration, and Matlab was used to archive the measurements to disk and for further processing. The research used the acceleration waveform of the machine vibrations due to the vibration transducer used.

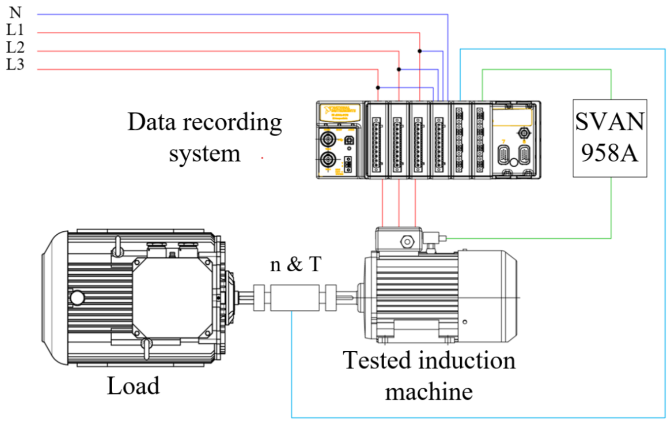

Figure 1: Diagram of the measurement system.

Selected measurement results of the machine vibration signal waveforms are shown in Figure 2. The figure shows the waveform of a healthy machine and a machine with 4 shorted turns in the stator winding. In both cases the machine was loaded with the rated torque.

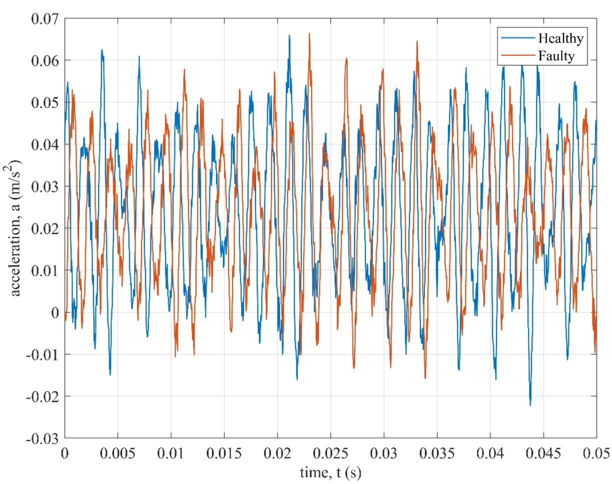

Figure 2: Waveforms of vibration acceleration for a healthy and faulty machine

III Selected results of diagnostic signal analysis

Due to the non-stationary nature of the machine's vibration waveforms, it was decided to use packet wavelet analysis. This analysis involves filtering the input signal into its approximate and detailed components. This is done using low pass and high pass filters respectively. In the next step, the approximation and detail can be filtered. As a result, the analysed signal is decomposed into a set of approximations marked with the letter A and details marked with the letter D, along with their variations depending on the level of decomposition. The whole process can be represented in the form of a decomposition tree, Fig. 3. The next step in the analysis was to calculate the energy of the approximations and details in the nodes of the decomposition tree at the lowest level.

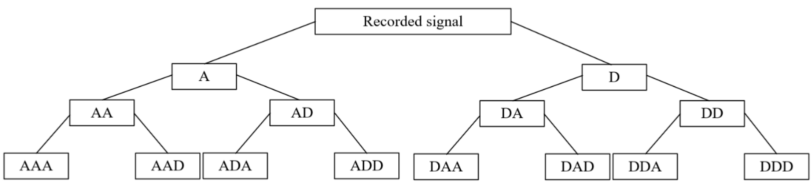

Figure 3: Structure of Wavelet Packet Decomposition

The vibration waveforms of a healthy machine and a damaged machine were selected for packet wavelet analysis for 9 load torque values, i.e. from no-load to a load of 105% of rated torque. For the damaged machine tests, the vibration waveforms were considered for the number of shorted turns from 1 to 4.

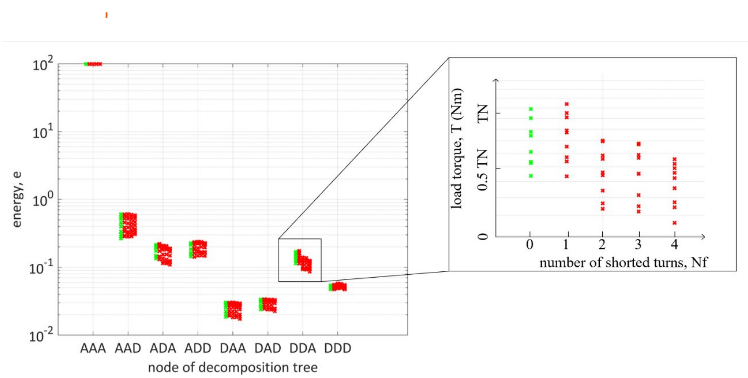

Figure 4: Energy of the machine vibration waveforms in the nodes of the decomposition tree.

The results of the packet wavelet analysis are shown in Figure 4. The healthy machine is marked in green and the damaged machine is marked in red. The figure shows the tendency that as the number of shorted turns increases, the percentage of energy transferred for the obtained ADA and DDA increases. This phenomenon would be almost impossible to observe with a smaller number of cases.

Further research was carried out to establish the relationship between machine vibration and the number of shorted turns in the stator winding. For this purpose, the correlation between these two quantities was calculated as follows.

$$\rho(A,B) = \frac{1}{N-1}\sum_{i=1}^{N}\left(\frac{A_i-\mu_A}{\sigma_A}\right)\left(\frac{B_i-\mu_B}{\sigma_B}\right) \tag{1}$$

where μA and σA are the mean and standard deviation of A; μB and σB are the mean and standard deviation of B.

The results of the correlation calculations are presented in Fig. 5.

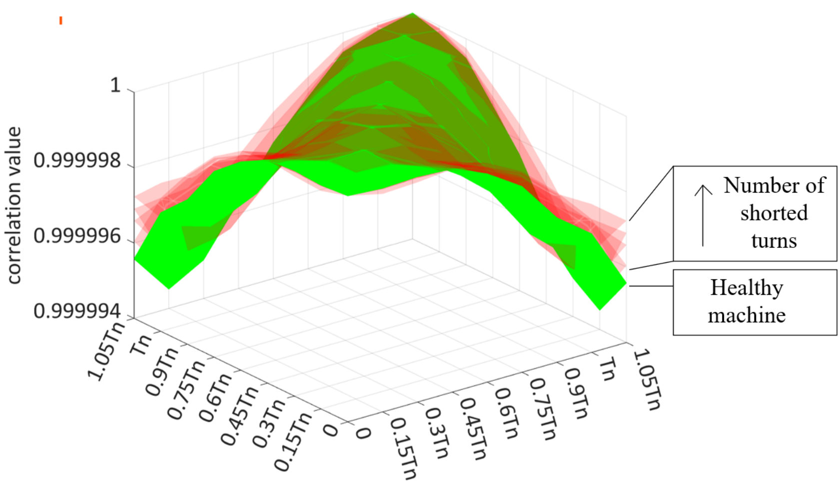

Figure 5: Correlation between vibration and the number of shorted turns.

The correlation results presented in Figure 5 clearly show the differences between the degrees of machine damage. At low load torque values, the correlation is weakest for a healthy machine. However, as the load torque increases, a stronger correlation can be observed.

IV Conclusions

The paper presents the results of vibration measurements of a damaged induction machine and the results of their analysis using packet wavelet analysis. Based on the results of the analysis, the correlation between the vibrations of the induction machine and the number of shorted turns of the stator winding is presented.

From the test results presented, it can be concluded that the method presented can be used to assess the condition of the windings of squirrel cage induction machines. The use of packet wavelet analysis is an indispensable tool for the analysis of aperiodic waveforms, such as the recorded vibration accelerations.

The conclusions and findings of this article may be particularly useful in classifying asymmetric defects. Further research suggests applications of machine learning that can assist in defect classification.

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