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Maciej Skowron

SUMMARY

„ Diagnostics of damage to the induction motors and permanent magnet synchronous motors using neural networks with deep learning ”

The doctoral thesis entitled: "*Diagnostics of damage to the induction motors and permanent magnet synchronous motors using neural networks with deep learning*" consists of 9 numbered chapters with a total length of 169 pages. The main aim of the dissertation is to analyze and assess the applicability of deep learning neural networks for the early detection of basic faults in induction and permanent magnet synchronous motors.

The first chapter of the thesis presents the state of the problem concerning the diagnostics of electrical motor failures. Based on a literature review of 255 items, the following thesis of the doctoral thesis was determined: **The use of the convolutional neural network enables the detection of the stator and rotor damage in induction and permanent magnet synchronous motors at a very early stage based on the direct analysis of the signals.**

The second chapter contains a detailed description of the damage to AC electric motors. Particular attention was paid to the problem of the stator winding turns and damage to the rotor of induction motors (SI) and permanent magnet synchronous motors (PMSM). The methods of mathematical modelling of the analyzed failures are presented in the third chapter. Both mathematical models and the results of experimental verification for the developed models of motors with damages to the stator and rotor windings have been presented.

The use of the basic methods of analysis in the diagnosis of faults is presented in chapter four. The described research results include, in particular, the application of the fast Fourier transform and the analysis of the symmetrical components. Extraction of damage symptoms based on the analysis of diagnostic signals was aimed at developing input vectors of shallow neural structures presented in chapter 6.

Because of the basic aim of the research related to the use of neural fault detectors, chapter 5 contains the characteristics of the basic structures of shallow and deep neural networks. Chapter five contains a detailed description of the operation and training methods of neural structures, the implementations of which are presented in chapters 6 and 7.

The sixth chapter presents the use of classical neural networks in the induction motors and PMSM faults diagnosis. The idea of the operation and experimental verification of damage detectors using the structure of a multilayer perceptron, self-organizing Kohonen maps as well as hybrid neural structures are described. The chapter ends with the analysis and evaluation of the usefulness

of shallow neural networks in the diagnostic process. The summary in chapter 6 emphasizes both the advantages of classical neural structures and the limitations resulting from the methods of developing their input vectors.

Chapter seven is the key point of the described doctoral dissertation. It presents the possibility of the direct analysis of diagnostic signals by the convolutional neural network. The developed diagnostic systems using the convolutional network in their structure are characterized by unattainable so far precision of the detection of the initial degree of defects with a very short reaction time to the occurring damage. The results of experimental research described in chapter 7 clearly showed the advantage of direct signal analysis by the deep neural network over the diagnostic methods known so far. Additionally, in the absence of formal rules for the design and tuning of deep neural networks, chapter 7 presents a detailed description of the impact of structure parameters and the training process on the effectiveness of the diagnostic system. The basic relationships between network parameters and the accuracy of fault detection presented in chapter 7 may provide a guide when designing diagnostic systems using deep convolutional networks.

In the eighth chapter of the doctoral thesis, 3 experimental research stands were presented, where measurements of diagnostic signals were carried out during modelling of the analyzed damages of induction motors and synchronous motors with permanent magnets. Moreover, a description of the developed application for examining the technical condition of the SI and PMSM using the diagnostic methods described in the dissertation was included.

The last chapter of the thesis presents the completed research works included in the doctoral dissertation. At the end of individual chapters, partial conclusions concerning the discussed issues are presented, while in chapter 9 general conclusions are formulated.

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