Fault diagnostics of permanent magnet synchronous motors based on deep neural networks and transfer learning

The development of modern enterprises following the idea of industry 4.0 directly forces the need to develop the fully-integrated systems in which the role of a human (expert) is gradually limited in favour of IT systems. The combination of the latest achievements in the field of computer science, neuroscience and electrical engineering enables the development of tools ensuring safety, as well as contributing to increasing the reliability of electromechanical systems. Today, permanent magnet synchronous motors (PMSM) are increasingly used in modern drive systems used in many industries and commercial applications. This fact is related to the dynamic development of control methods for these machines thanks to the popularization of microprocessor systems. The frequency converters used, which are the key elements of the drive systems, ensure efficient motor operation, enable smooth start-up and speed control while maintaining a high load torque. Nevertheless, despite the high quality of PMSM motor control systems, they are not fully separated from the factors influencing their technical condition. Due to the above, during their operation in industrial drive systems, various types of defects may arise, limiting or preventing further operation of the machine.

Currently, one of the main aspects when selecting the components of drive systems is their reliability and, above all, the possibility of continuous monitoring in real-time. Only then is it possible to ensure high production efficiency, quick response to failures, as well as effective and easy operation of the entire line. In addition, the trend of continuous improvement of automated electromechanical systems is currently observed on a large scale both in industrial applications and in the fields related to electromobility.

Despite the many similarities between the types of electric motors, it is not possible to transfer diagnostic systems directly from one machine to another. The problem of the universality of the system is noticeable especially in the case of early detection of damage to machines with different nominal parameters. Therefore, there is a real need to develop universal diagnostic systems, which allows changing the type of motor or its rated parameters. Moreover, a universal system would ensure the full use of information from mathematical models of objects. As a result, the implementation of new system functions (recognition of a different type of damage) would not require physical damage to the object. This fact is of particular importance in the case of high-power motors, where physical damage modeling is associated with a high risk.

The fulfilment of the above requirements for diagnostic systems can be realized with the use of deep neural structures, the training process of which is carried out by the idea of transfer learning. Transfer learning is a technique that uses the features of a system acquired during the training process for one problem, in another but related task. This approach creates an opportunity to develop universal (used for various types of electric motors) and scalable (used for machines with different rated parameters) diagnostic systems for AC motors.

The aim of the research project is the development and verification (simulation and experimental) of the modern methods of diagnostic of the permanent magnet synchronous motor (PMSM) damages using transfer learning of a deep neural network. The scope of research work includes the analysis of damage to permanent magnets and short-circuits in the stator windings of the PMSM motor, as well as mixed damage. Because of the destructive nature and high dynamics of the analyzed PMSM damage, special attention is paid to ensuring a very fast detection of defects at the earliest possible stage. This results both in the rapid escalation of damage to the stator windings, as well as the negative impact on the technical condition of permanent magnets. Therefore, in the research, the direct analysis of the measured signals is used, with the omission of known methods of signal analysis. This approach makes it possible to shorten the reaction time of the diagnostic system to the damage many times over. As part of this project, it is assumed to develop diagnostic systems based mainly on deep convolutional networks. The use of the transfer learning technique of deep convolutional networks will ensure precise and quick diagnostics of PMSM damage. Moreover, the motor fault detectors based on the transfer learning method ensure the universality as well as scalability of the diagnostic applications.