Aim of the research / research hypothesis

Permanent magnet synchronous motors (PMSMs) have become very competitive compared to other types of electrical machines due to lower losses, higher torque to weight ratio, better dynamic characteristics, low noise emission, simple compact design and easy maintenance. For this reason, PMSMs are used in many applications that require high efficiency and precise torque control in a variety of operating conditions, including robotics and electric vehicles. In such applications, these motors are subjected to high physical and thermal loads. Overloading the PMSM motor can affect to faster machine damage, and unexpected damage or failure of the drive can lead to very high repair or replacement costs. Therefore, diagnostics of this type of machines seems to be necessary (e.g. it can help in planning preventive maintenance). Symptoms of damage can be sought in electrical signals (current, voltage), magnetic flux, acoustic noise, mechanical vibrations and local temperature changes. Damage should be detected and diagnosed in its initial state to prevent further spread. Early detection of damage will allow to plan the motor overhaul, which will reduce the cost of repairing the device or delays and losses in production.

The authors of this proposal believe that based on an appropriate analysis of selected signals, available directly in the drive system or signals calculated in the vector control structure, it will be possible to detect early damage symptoms and inference about the drive state. A diagnostic system will be developed, based on external and internal signals of the vector control structure, their processing and analysis using analytical and neural methods, which will automatically detect and locate the fault.

The aim of this project is to develop new methods of detection and diagnostics of electrical and mechanical faults in permanent magnet synchronous motor drives using advanced signal processing algorithms and neural networks. The developed hybrid diagnostic methods will be tested in simulation and experiments.

Research method / methodology.

Various electrical and mechanical damages of the PMSM will be considered, such as: turn-to-turn short-circuits of the stator winding, phase-to-phase short-circuits, demagnetization of permanent magnets, bearing damages, misalignment, unbalance, eccentricity. Their impact on the operation of the vector-controlled drive will be verified by extensive simulation tests using both circuit and field-circuit mathematical models. The simulation results will be verified using experimental tests realized on the laboratory set-up developed under the project. Based on these simulation and experimental tests, suitable diagnostic signals will be selected (including signals available in the control structure), enabling the detection of selected failures and distinguishing the damages causing similar symptoms. The classical (frequency-domain methods, as: FFT and high resolution techniques like: MUSIC, ESPRIT, BISPECTRUM) and advanced signal processing methods (time-frequency methods: Short-Time Fourier Transform – STFT, Continuous Wavelet Transform – CWT, demodulation techniques e.g.: Principal Components Analysis – PCA, Hilbert-Huang Transform – HHT) will be used for fault symptoms extraction. On the basis of them, the PMSM detection and diagnostics algorithms will be developed, using algorithmic methods and artificial intelligence methods (supervised and unsupervised neural networks), implemented using hardware and software tools. The developed diagnostic algorithms will enable early detection and differentiation of the considered damages, i.e. development of a comprehensive fault diagnosis system for the PMSM motor drive A modern laboratory setup will be built, equipped with a PMSM motor with a suitably designed stator winding (for modeling the short-circuits) and the possibility of replacing the efficient ("healthy") rotor with damaged rotors of magnetic and/or mechanical nature.

Impact of results (development of science)

Research planned under the project is located in the current stream of research and development related to the problems of diagnostics of controlled drive systems, in particular servo drives. They are also of interest of the industry in the field of robotics and hybrid or completely electric means of transport. In addition, the planned research fits well in rapidly growing field of fault-tolerant control methods for complex dynamic systems.

In addition to theoretical developments in the detection and localization of the PMSM damages, a laboratory drive system with a PMSM controlled by a digital signal processor (DSP) and field-programmable gate array (FPGA) that realizes on-line algorithms for detection, diagnosis and localization of the motor damage will be built. The setup after completing the project will be used for further experimental and research work on drive systems with PMSMs. Selected research results will be used in the postdoctoral proceedings of main investigators of this project as well as in the planned doctoral dissertations of two PhD students. The results of the work will be published in renowned journals (IEEE, IET) and presented at international and national conferences, in order to confront and discuss them with other experts. The most valuable solutions, from the point of view of possible future commercialization, will be submitted for patent protection.