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Condition Monitoring of Rolling Bearings in PMSM Drives under Variable Operating Conditions

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INTRODUCTION & AIM

The dynamic development of industry, driven by the ongoing automation of production processes, digitalization, and increasing demands for energy efficiency, has led to the widespread adoption of electric drive systems. It is estimated that motor-driven systems account for approximately 70% of total electricity consumption in industry, highlighting their critical importance to the global economy. Statistical analyses indicate that rolling bearing failures account for approximately 13% to as much as 70% of all electrical machine faults, depending on the supply voltage level (Fig. 1). Importantly, the early stages of bearing damage often do not produce immediately observable symptoms in the operation of the drive system; however, their progression can lead to severe consequences, such as damage to the rotor, stator, or even complete system failure. From an economic perspective, unplanned downtime can result in losses reaching several thousand euros per hour, which further justifies the need to develop effective diagnostic methods.

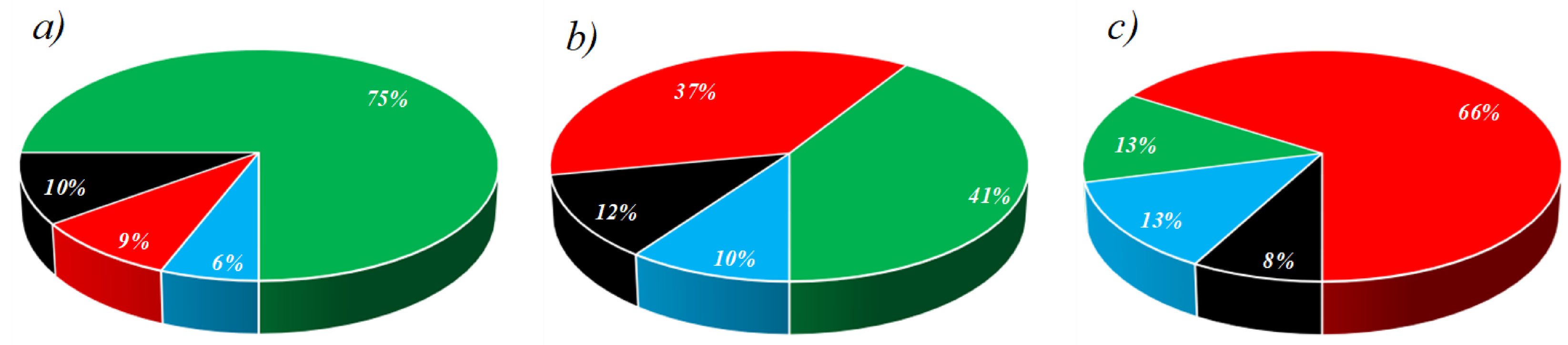

Fig. 1 Failures related to faults occurring in electric machines, classified by voltage level: a) low-voltage machines, b) medium-voltage machines, c) high-voltage machines.

The aim of this study is to develop and validate a comprehensive approach to the diagnosis of rolling bearing damage in permanent magnet synchronous motors (PMSMs), based on the analysis of multiple diagnostic signals under various operating conditions. Attention is given to evaluating the influence of motor load and current controller parameters within a field-oriented control (FOC) scheme on the effectiveness of fault detection. An important aspect of the work also includes the analysis of data acquisition processes, signal preprocessing, and the extraction of diagnostic feature.

METHOD

The experimental setup allows for the testing of bearings in various conditions: no-faulty, with damage to the inner race, outer race, and rolling elements. The electromechanical system enabled the simulation of various operating conditions, allowing for a precise assessment of the impact of damage on the characteristics of measurment signals. The main component of the system is a PMSM motor (Lenze MCS14H15), rigidly coupled to a load motor (Lenze MCS14H32). Power supply and speed control are provided by a TWERD inverter with a fiber-optic interface.

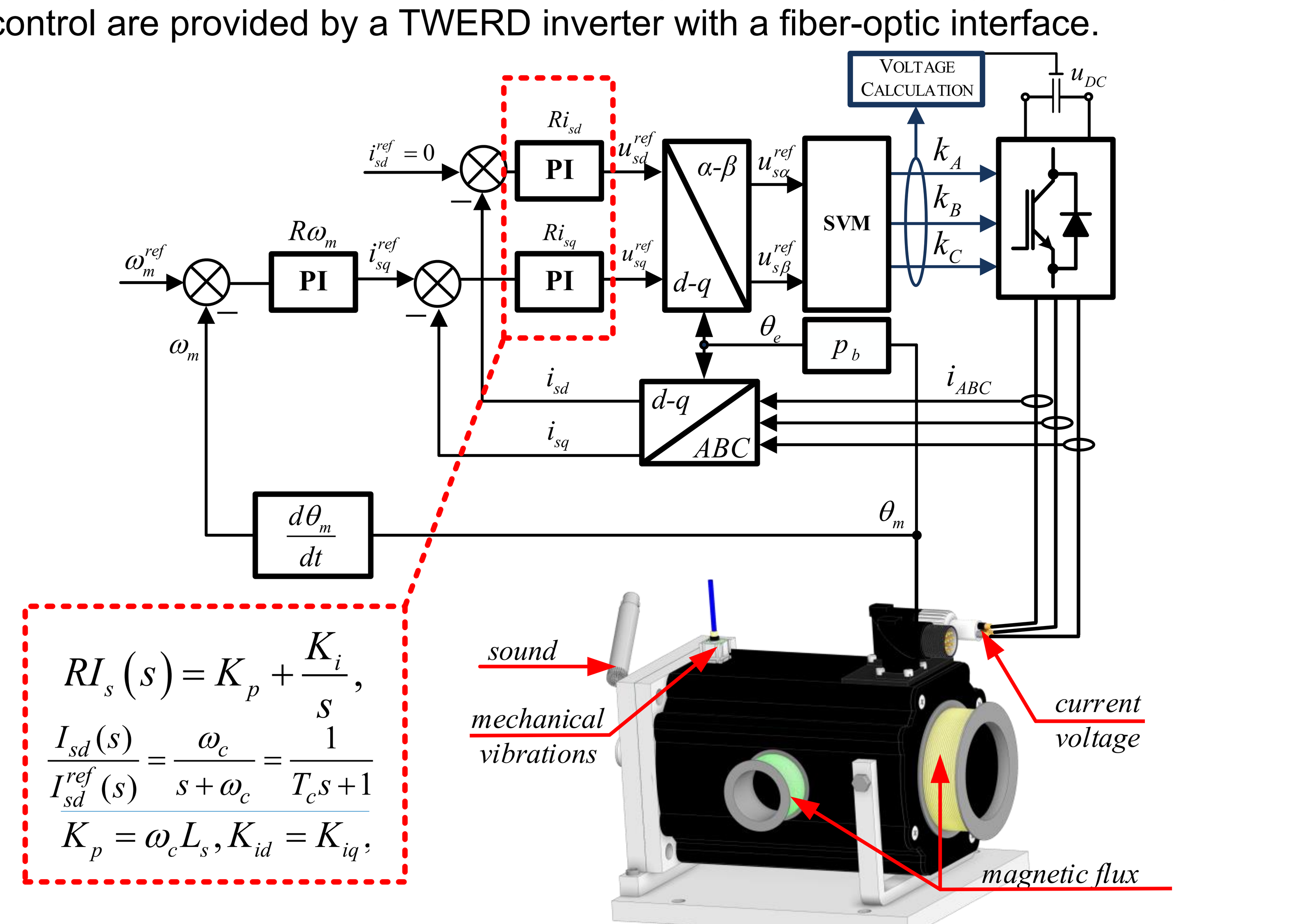

Fig. 2 Schematic of a measurement system with a field-oriented control (FOC) system implemented, illustrating the concept of tuning the controller dynamics by adjusting the bandwidth, with measurement signals highlighted.

RESULTS & DISCUSSION

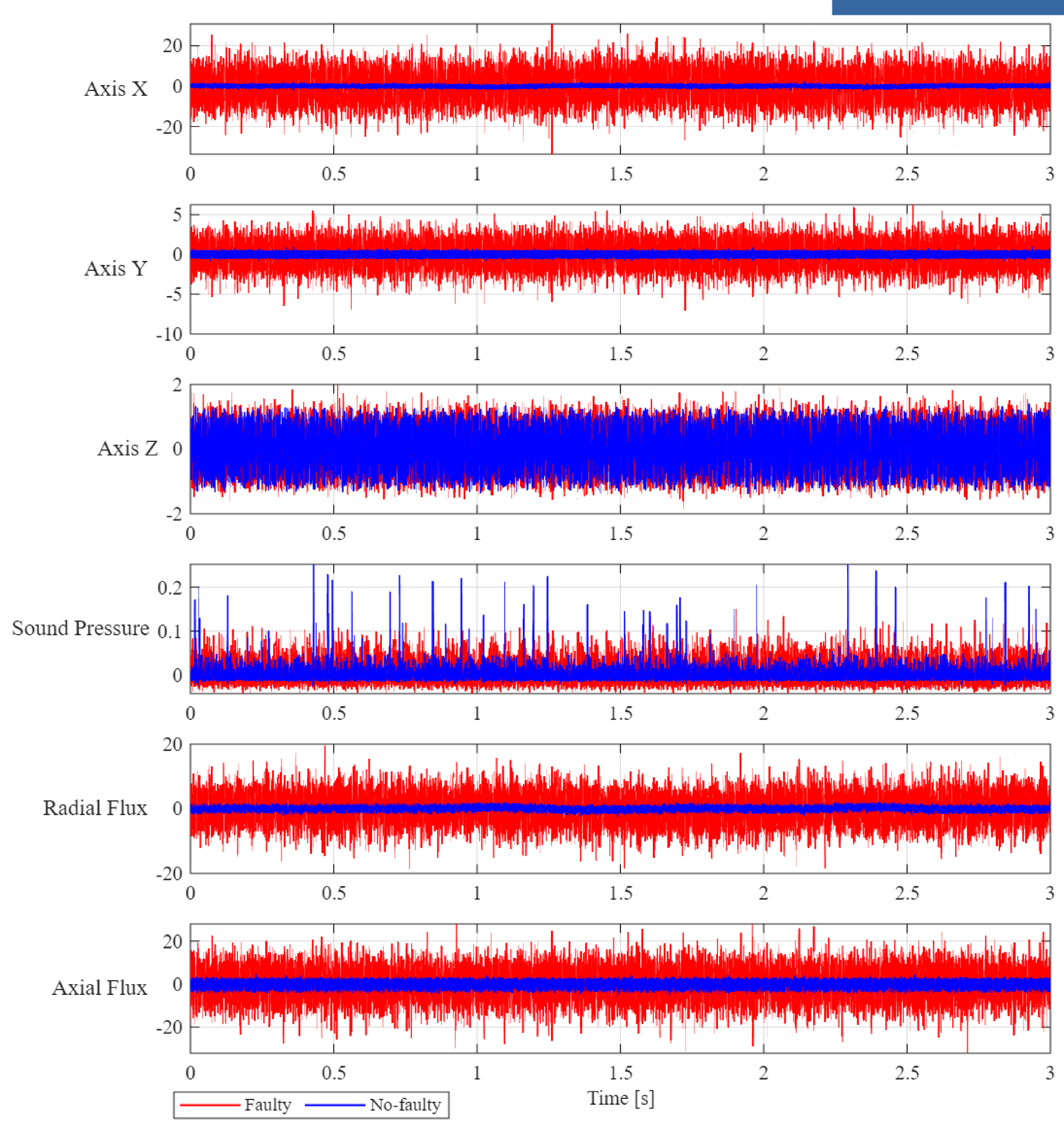

Fig. 3 Example of analysed signals from a PMSM motor under operating conditions: frequency f = 80 Hz, load torque T_L = 80%T_M, bandwidth ω_c = 700

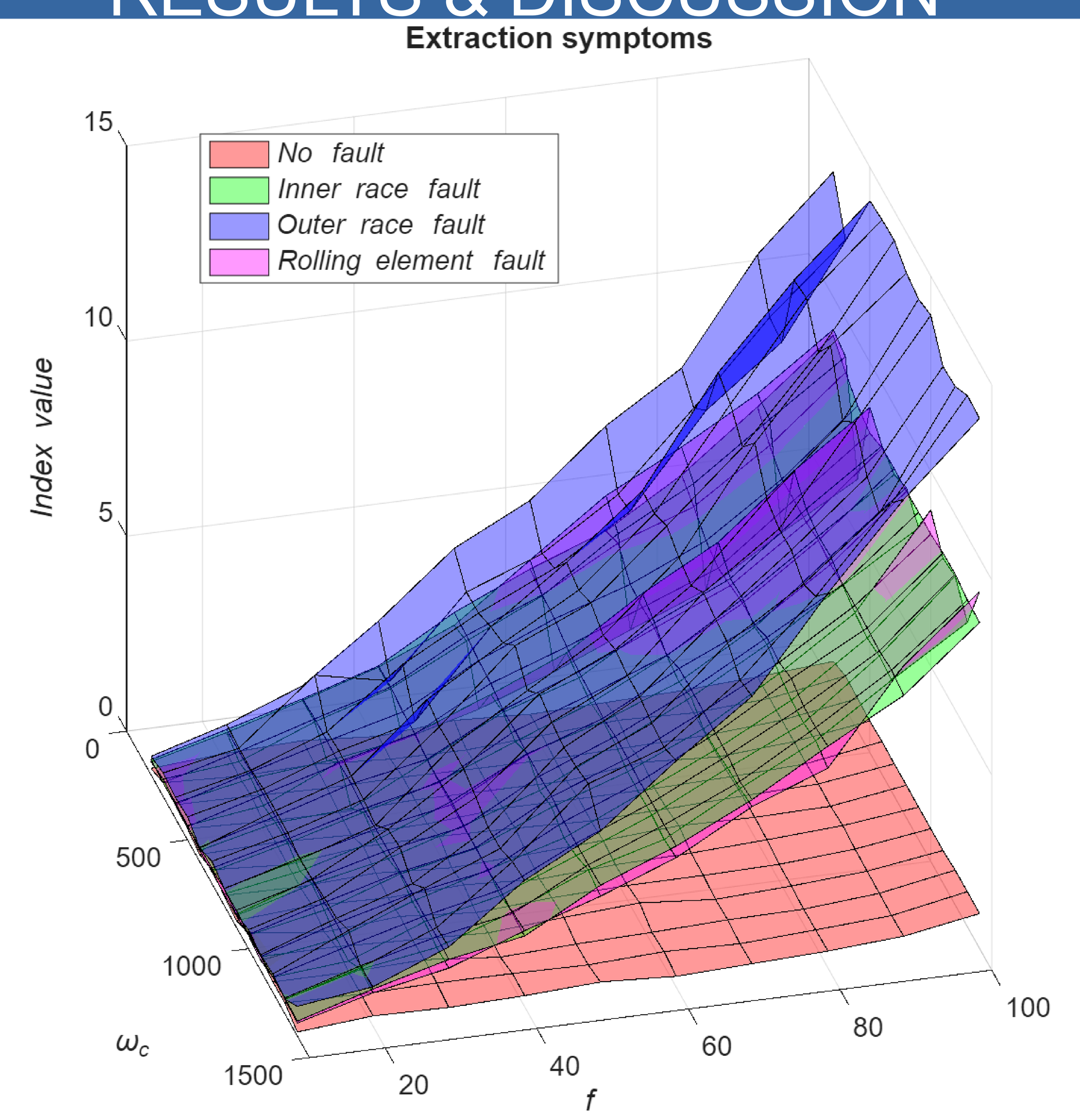

Fig. 4 Extraction of vibration signal features along the X-axis for variable frequency f = var and bandwidth ω_c = var, at a load torque of T_L = 80%T_M.

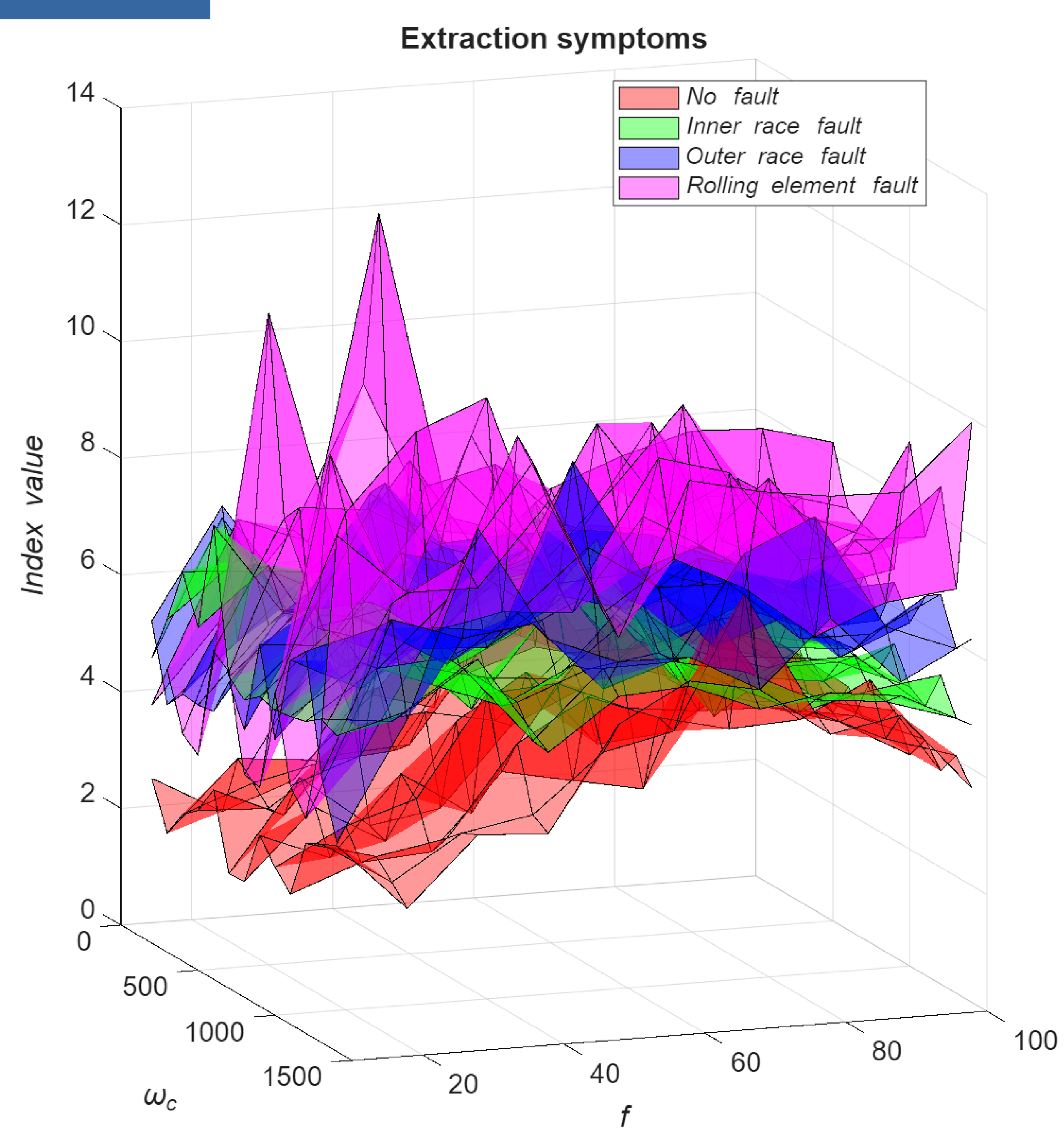

Fig. 5 Extraction of radial flux signal features for variable frequency f = var and bandwidth ω_c = var, at a load torque of T_L = 80%T_M.

The parameters of the controllers in the control system have a significant impact on diagnostic results, as the control structure compensates for fault symptoms. At the same time, operating conditions—particularly the load level—strongly determine the effectiveness of diagnostics; fault detection rates typically increase as the load increases. The use of multiple measurement signals allows for the compensation of the effects of variable operating conditions. The analysis confirms that a single signal does not provide universally reliable results; therefore, a multi-signal approach increases reliability and improves the effectiveness of fault detection.

CONCLUSIONS

Presents an approach to diagnosing bearing damage in PMSM motors based on the analysis of current, voltage, vibration, acoustic emission, and magnetic flux signals. This method enables a more comprehensive and reliable assessment of the machine's condition than techniques based on a single signal. Analyses, combined with feature extraction techniques, enable the identification of fault-sensitive indicators for various types of bearing defects. The study shows that there is no universal diagnostic measure, as its effectiveness depends on operating conditions, load level, and control parameters. Attention is given to the influence of the control structure, especially the bandwidth of current controllers, on the visibility of measured diagnostic signals.

Incorporating multiple signal sources enhances diagnostic performance, flexibility, and practical applicability, supporting the development of more reliable and cost-effective condition monitoring systems.

REFERENCES

M. Krzysztofiak, T. Zawilak, G. Tarchała, "*Online control signal-based diagnosis of interturn short circuits of PMSM drive*," *Archives of Electrical Engineering*, vol. 72, no. 1, 2023, doi: 10.24425/aee.2023.143692.
A. J. M. Cardoso, "Diagnosis and Fault Tolerance of Electrical Machines," Power Electronics and Drives, 2018.
Falkner, Hugh, and Shane Holt. "Walking the torque: Proposed work plan for energy-efficiency policy opportunities for electric motor-driven systems." (2011).

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