# INTRODUCTION

Interior permanent magnet synchronous motors (IPMSM) find their application in high dynamics and high precision drives. Due to presence of permanent magnets (PMs), torque and power density of the motors is significantly higher comparing to the other AC machines. Unlike the surface PM motors (SPMSMs) where permanent magnets are attached to the surface of the rotor, IPMSM is more reliable, maximum speed is usually higher. The only drawback of the motor is its cost, as nowadays technologies do not allow creating PMs artificially with equivalent flux density comparing to the ones from rare earth materials.

The PMs are implemented into the rotor structure in the IPMSM. Due to this geometry, rotor of the motor has saliency. It leads to the several consequences: motor torque is created not only from PMs, but also from the reactive component caused by the difference between direct and quadrature axis inductances of the rotor; effect of saturation and cross-coupling on the motor behavior is significantly higher comparing to the non-salient analog.

**Thesis actuality.** Conventional vector control algorithms demand information about six motor parameters for proper operation. Moreover, parameters are considered as constant values. Inductances variation due to saturation have to be considered in the motor model and control algorithm in order to avoid performance deterioration due to parameter mismatch. Therefore, derivation of the motor model where saturation and cross-coupling are considered is an open-ended question and has to be solved. Several approaches are proposed to determine inductances considering saturation effects. The most of the methods require special tests or ignore system nonlinearities with the purpose of simplification of the calculation, but it leads to output data accuracy deterioration.

On the other hand, if motor saturation is comparatively small, development of more complex algorithm with considered saturation is questionable. In this manuscript, verification of validity of usage of the control based on the non-saturated model for the small saturated IPMSMs is made.

Another aspect of IPMSMs control that is also considered in the manuscript is online estimation of mechanical parameters of the motors. Proper estimation of the moment of inertia, friction coefficient and load torque are highly important in high dynamic applications, such as robotics or servo drives.

**Thesis relation with science programs, topics and plans.** The thesis is based on the research made in the Automation of electromechanical systems and the electrical drives department of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" and in the School of Engineering of the Warwick University during student exchange program.

**Research goals and tasks.**

The *goal* of the thesis lies in the improvement of efficiency and performance of the electromechanical systems based on IPMSMs by means of development of the advanced control techniques. The *tasks* of the thesis are following:

1. Survey of the existed methods for inductance determination considering saturation for the IPMSMs.
2. Development of the tests for inductance determination methods that will combine simplicity, high accuracy and convenience of usage.
3. Development of the speed and position control algorithms for the IPMSMs. Verification of validity of usage of the control based on the non-saturated motor model for the small saturated IPMSMs.
4. Development of the position control algorithm with adaptation to the mechanical parameters for the IPMSMs.

*Research object.* Processes of the control of the electromechanical energy conversion of the IPMSMs.

*Research subject.* Speed and position control algorithms of the IPMSMs with adaptation to the mechanical parameters.

*Research methods*. Research is based on the modern control theory of the nonlinear systems. Following methods are used: second Lyapunov method, feedback linearizing control method and methods of modelling and experimental research.

**Scientific novelty of the obtained results** is following:

1. Novel speed and position control algorithms for IPMSM is designed. Despite of the existing analogues, it allows decoupling of direct current component control subsystem and mechanical coordinates control subsystem. From the experimental and simulation analysis follows that proposed algorithms can be used for small saturated IPMSMs without significant performance degradation.

2. Novel position control algorithm with online adaptation to the mechanical parameters for the IPMSM is designed. Unlike the existed algorithms, mechanical parameters are observed during operation and algorithm adapts to its variation.

**Practical value of the obtained results.** Designed speed and position algorithms provide asymptotic tracking of the controlled coordinates that leads to improvement of the high-dynamics systems performance. Designed adaptive position algorithm observes mechanical parameters during operation that allows improving system performance especially if mechanical parameters are variable values.

**Publications.** The main idea of the Master thesis is presented in 4 scientific articles, where 1 of them is an IEEE conference paper and 3 are published in Ukrainian scientific journals.

Publications:

1. Rodkin D., Zinchenko O., Peresada S. "Survey of the interior permanent magnet synchronous motor models considering saturation and cross-magnetization", International scientific and technical journal of young scientists, graduate students and students "MODERN PROBLEMS OF ELECTRIC POWER ENGINEERING AND AUTOMATION", Kyiv, Ukraine, 2020.

2. Rodkin D., Zinchenko O., Peresada S., Kiselychnyk O. "Inductance determination of interior permanent magnet synchronous motor considering saturation", International scientific and technical journal of young scientists, graduate students and students "MODERN PROBLEMS OF ELECTRIC POWER ENGINEERING AND AUTOMATION", Kyiv, Ukraine, 2020.

3. S. Peresada, V. Reshetnyk, D. Rodkin, O. Zinchenko, "Linearizing speed control and self-commissioning of interior permanent magnet synchronous motors", Bulletin of the National Technical University "KhPI". Problems of automated

electrodrive. Theory and practice, Kharkiv, 2019. no. 9, vol. 1334. pp. 36-42. (in Ukrainian).

4. S. Peresada, Y. Nikonenko, V. Reshetnyk and D. Rodkin, "Adaptive position control and self-commissioning of the interior permanent magnet synchronous motors," 2019 IEEE International Conference on Modern Electrical and Energy Systems (MEES), Kremenchuk, Ukraine, 2019, pp. 498-501.