



MINISTRY OF EDUCATION AND SCIENCE OF
UKRAINE CENTRAL UKRAINIAN NATIONAL
TECHNICAL UNIVERSITY
Department of ETS and EM



SYLLABUS FOR THE COURSE

Course title	MODELING OF ADJUSTABLE ASYNCHRONOUS ELECTRIC DRIVE SYSTEM
Lecturer	Natalia GARASOVA, Candidate of Technical Sciences, Associate Professor Department of ETS and EM
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Scope and characteristics of the course	Elective module, comprising 2 content modules. Assessment method: module test. Total number of credits – 4, hours – 120. Format: face-to-face (offline) / distance learning (online). Language of instruction: English.
Consultations	Consultations are held in accordance with the timetable posted on the moodle.kntu.kr.ua platform; via Zoom video conferences, email, Viber or Telegram by arrangement.
Prerequisites	There are no specific requirements, but the effectiveness of learning the material will be significantly improved if the student has a basic understanding of automated electric drives.

1. Aims and objectives of the course

The aim of the course ‘Modeling of adjustable asynchronous electric drive system’ is to equip students with in-depth theoretical knowledge and research skills relating to the mathematical and computer modelling of induction motor drives, analysing their electromagnetic, mechanical and energy processes, synthesising and investigating control systems, as well as assessing the impact of control laws and operating modes of electric drives on the electricity consumption and energy efficiency of process plants.

The course aims to develop the ability to use mathematical and simulation models as tools for researching, forecasting and optimising the operating modes of modern controlled electric drives in electricity consumption and energy management systems.

Objectives of the course:

- an in-depth study of mathematical models of an induction motor in natural three-phase and orthogonal coordinate systems, and an analysis of the assumptions, parameters and limits of application of various models;
- to investigate coordinate transformations and their use in modelling scalar and vector-controlled electric drives;
- to construct structural and simulation models of an induction motor, a frequency converter, a mechanical load and automatic control systems in the MATLAB/Simulink and Simscape Electrical environments;
- modelling of steady-state and transient operating modes of a controlled electric drive, and analysis of dynamic, mechanical and energy characteristics;
- investigating scalar and vector control systems, and comparing their dynamic and energy characteristics;
- synthesis and tuning of automatic control loops for speed, torque and process parameters of electromechanical installations;
- modelling of frequency-controlled electric drives for pumping, ventilation and other process machinery, taking into account load characteristics;
- assessment of electricity consumption, power losses, efficiency and energy-saving potential when using a variable-speed electric drive;
- conducting computational experiments, parametric studies, sensitivity analysis of models and justifying optimal parameters for electric drive systems;
- developing skills in the critical analysis of modelling results, their verification and application in the completion of research and master’s theses.

2. Learning outcomes

Upon completion of the course, the student should **be familiar with:**

modern approaches to the mathematical description of induction motors in various coordinate systems; the principles of constructing structural, mathematical and simulation models of electromechanical systems; methods of coordinate transformation; the principles of scalar and vector control of induction motors; the structures of automatic control systems for speed, torque and process parameters; methods for analysing steady-state and transient modes; methods for evaluating the power characteristics and energy efficiency indicators of a controlled electric drive.

The candidate must **be able to:**

- formulate a mathematical description of an induction motor and an electromechanical system; determine and justify the parameters of a mathematical model; implement models in MATLAB/Simulink and Simscape Electrical;
- carry out simulations of start-up, braking, steady-state and controlled modes;
- build and investigate models of scalar and vector frequency-controlled electric drives;
- to synthesise control loops;
- model the interaction of the electric drive with pumping, ventilation and other process mechanisms;
- analyse electromechanical and energy characteristics;
- compare alternative control structures;
- assess the potential for reducing electricity consumption and improving energy efficiency;
- interpret the results of computational experiments and justify engineering decisions.

For students on the ‘Electrical Power Consumption Systems’ study programme, the learning outcomes are additionally focused on investigating the impact of a variable-speed electric drive on the operating modes of power consumption systems, electrical loads and the quality of electricity utilisation.

For students on the ‘Energy Efficiency and Energy Consumption Management’ programme, the emphasis is on modelling the energy consumption of industrial plants, assessing energy-saving potential, optimising operating modes and using models to justify energy-efficient control algorithms.

To acquire soft skills: the ability to independently formulate and formalise a research problem, critically assess the adequacy of mathematical models, interpret the results of computer experiments in a reasoned manner, work with scientific and technical information, present research findings and justify engineering decisions.

3. Course policy and academic integrity

Students are expected to adhere to the principles of academic integrity and to be aware of the consequences of breaching them.

In organising the educational process at the Central Ukrainian National Technical University, students, lecturers and the administration act in accordance to: the Regulations on the organisation of the educational process; the Regulations on the organisation of the study of elective subjects and the formulation of individual study plans at the higher education institution; and the Central Ukrainian National Technical University's Code of Academic Integrity.

4. Course syllabus

Content Module 1.

Topic 1. Lectures 1–2. General characteristics and classification of induction motor models. Mathematical models of induction motors in natural phase coordinates

Topic 2. Lectures 3–4. Coordinate transformations. Mathematical models of an induction motor in orthogonal coordinates.

Topic 3. Lectures 5–6. Induction motor models in the Simpowersystems library/

Topic 4. Lectures 7–8. Modelling of speed control systems for an induction motor.

Content Module 2.

Topic 5. Computer simulation models of a frequency-controlled asynchronous electric drive for a pumping station

Lecture 9. Generalised block diagram of the automatic head control system in the pumping station main pipeline based on a frequency-controlled asynchronous electric drive. Computer simulation model of the controlled object. Computer simulation model of the actuator.

Lecture 10. Synthesis of the automatic head control system in the pumping station main pipeline

Lecture 11. Generalised computer simulation models of the scalar and vector frequency-controlled asynchronous electric drives of a pumping station

Topic 6. Computer simulation modelling of operating modes of a frequency-controlled asynchronous electric drive at a pumping station

Lecture 12. Modelling of operating modes of a scalar frequency-controlled electric drive in a pumping station

Lecture 13–14. Modelling of operating modes of a vector frequency-controlled electric drive for a pumping station

Topic 7. Computer simulation models of a frequency-controlled asynchronous electric drive for a fan unit

Lecture 15. Generalised block diagram of the automatic pressure control system for a fan unit based on a frequency-controlled asynchronous electric drive. Computer simulation model of the controlled object. Computer simulation model of the actuator.

Lecture 16. Synthesis of the automatic pressure control system for a fan unit.

5. Assessment criteria and methods

Assessment methods: observation of students' learning activities, oral questioning, written tests.

Form of final assessment: **credit**.

The criterion for successful learning is the student's attainment of the minimum pass marks for each learning outcome.

The objectivity of the assessment of students is ensured through the use of a cumulative system of awarding marks for learning outcomes on each topic of the educational component throughout the semester. During the semester, a student may obtain a maximum of **100 marks**, comprising: **50 marks** for the first module and **50 marks** for the second module.

When assessing full-time students, the following results are taken into account:

- classroom work (practical sessions);
- independent study (review of lecture material and literature);
- assessments;
- questioning;
- delivering a presentation.

The range of marks for the work completed is shown in the table.

Type of work	Mark range
Completion of a practical task	3...5
Test answers	0.4 for each correct answer
Poll	1...2
Completing independent study tasks	1...2
Delivering a talk / presentation	2...4

Maximum marks are awarded according to the types of work specified in the table.

Topic title	Practical work	Test	Quiz	Independent work	Presentation	Total
Content Module 1						
Topic 1. General characteristics. Mathematical models of AD in natural phase coordinates	–	–	–	4	4	8
Topic 2. Coordinate transformations. Mathematical models of AD in orthogonal coordinates	–	–	2	4	–	6
Topic 3. Asynchronous machine models in the Simscape Electrical library	10	–	2	4	–	16
Topic 4. Modelling of AD speed control systems	10	4	2	4	–	20
Total for Module I	20	4	6	16	4	50
Content Module 2						
Topic 5. Computer simulation models of a frequency-controlled asynchronous electric drive for a pumping unit	10	–	2	6	–	18

Topic 6. Computer-based simulation modelling of the operating modes of a frequency-controlled asynchronous electric drive at a pumping station	10	–	2	6	–	18
Topic 7. Computer simulation models of a frequency-controlled asynchronous electric drive for a fan unit	–	4	2	4	4	14
Total for Module II	20	4	6	16	4	50
Total for the term	40	8	12	32	8	100

- *Completion and defence of practical assignments.* The course comprises 16 hours of practical sessions (8 two-hour sessions), organised into 4 thematic practical assignments. The maximum mark for a candidate's work in a single two-hour practical session is 5 marks. The total maximum number of marks for the practical sessions is 40 marks.

Assessment of the completion and defence of practical assignments is carried out according to the following criteria:

Number of marks	Assessment criterion
5	The assignment has been completed in full and correctly. The candidate demonstrates a high level of theoretical knowledge, correctly applies calculation or research methods, and justifies the results and conclusions obtained. The practical work has been formatted in accordance with the requirements and successfully defended. The intended learning outcomes have been fully achieved.
4	The assignment has generally been completed correctly, although there are some inaccuracies or insufficient justification of the results. The student understands the basic principles and can explain the results obtained with the help of the lecturer. The programme's learning outcomes have been fully achieved.
3	The answer is insufficiently substantiated and well-reasoned; it demonstrates the ability to apply knowledge in practical work, but contains certain inaccuracies and indicates an incomplete grasp of the learning outcome. The learning outcomes have been partially achieved.
1–2	The task has been completed only partially or in a piecemeal manner; significant errors have been made in calculations or in modelling; the student demonstrates isolated elements of understanding of the material but requires substantial assistance from the lecturer; the results and conclusions obtained are insufficiently substantiated.
0	Failure to complete practical exercises (absence from the practical session), which makes it impossible to assess whether the programme's learning outcomes have been achieved.

- *Test assessments.* Two module-based test assessments are held during the semester via the distance learning system: the first covers topics 1–4, the second covers topics 5–7. Each test comprises 10 questions and is marked out of a maximum of 4 marks (0.4 marks for each correct answer).

Marking scheme and criteria for assessing test performance

Number of marks	Assessment criteria
0–4	10 test questions per module. 0.4 marks for each correct answer

- *Oral assessments.* These take place during practical sessions. Six assessed oral assessments are scheduled throughout the semester – three in each content module. The maximum mark for a single oral assessment is 2 marks. The total is 12 marks.

- *Completion of independent study tasks.* This involves taking lecture notes and preparing answers to selected review questions for each lecture (16 lectures in total). A maximum of 2 marks is awarded for each lecture. Answers are assessed on their completeness, logical coherence and depth of understanding.

Assessment criteria for independent study tasks:

Number of marks	Assessment criteria
2	The independent study question has been correctly addressed; the student demonstrates an understanding of the essence of the material, logical coherence and independence in its presentation; provides well-reasoned justification for their opinion; the answer contains well-founded conclusions. This demonstrates full mastery of the theoretical knowledge
1	The assignment is insufficiently substantiated and well-thought-out; it demonstrates the ability to apply knowledge in practical activities, but contains certain inaccuracies and indicates an incomplete grasp of the learning outcome. Competencies are developing, but at a basic level; the learning outcomes have been partially achieved.
0	Failure to complete the tasks, which makes it impossible to assess the development of competences and the attainment of the programme's learning outcomes.

- *Presentation.* Two presentations on topics chosen by the student are scheduled during the semester – one in each content module. The maximum mark for a single presentation is 4 marks. The total maximum is 8 marks.

Grading scale: national and ECTS

Total marks for all types of learning activities	ECTS mark	Grade on the national scale
		for a pass
90 – 100	A	Pass
82–89	B	
74–81	C	
64–73	D	
60–63	E	
35–59	FX	Fail, with the option to retake
0–34	F	Fail, with compulsory retake of the module

6. Recommended reading

Core

1. Abu-Rub H., Iqbal A., Guzinski J. **High Performance Control of AC Drives with MATLAB®/Simulink**. 2nd ed. Hoboken : John Wiley & Sons, 2021. 624 p. DOI: 10.1002/9781119591313.
2. Perelmuter V. **Electrical Drive Simulation with MATLAB/Simulink: Selected Technologies**. Boca Raton : CRC Press, 2024. 272 p. ISBN 978-1-032-49555-2. DOI: 10.1201/9781003394419.
3. Selvamathi R., Subramaniaswamy V., Indragandhi V. **Electric Motor Drives and their Applications with Simulation Practices**. London : Academic Press, 2022. 507 p. ISBN 978-0-323-91162-7. DOI: 10.1016/C2020-0-04631-1.
4. Krause P. C., Wasynczuk O., O'Connell T. **Introduction to the Analysis of Electromechanical Systems**. Hoboken : Wiley–IEEE Press, 2022. 256 p. ISBN 978-1-119-82999-7. DOI: 10.1002/9781394329847.
5. Boldea I. **Electric Drives**. 4th ed. Boca Raton : CRC Press, 2026. 770 p. ISBN 978-1-032-78286-7. URL: [CRC Press / Routledge](https://www.crcpress.com/9781032782867) (дата звернення: 23.09.2026).

Further reading

6. Azab M. **A Review of Recent Trends in High-Efficiency Induction Motor Drives**. *Vehicles*. 2025. Vol. 7, No. 1. Art. 15. DOI: 10.3390/vehicles7010015.
7. Ding C.-W., Tung P.-C. **A New Approach to Field-Oriented Control That Substantially Improves the Efficiency of an Induction Motor with Speed Control**. *Applied Sciences*. 2025. Vol. 15, No. 9. Art. 4845. DOI: 10.3390/app15094845.
8. Шуруб Ю. В., Попович О. М., Бібік О. В. **Підвищення енергетичної ефективності регульованого електроприводу одноциліндрового поршневого компресора**. *Технічна електродинаміка*. 2024. № 4. С. 63–72. DOI: 10.15407/techned2024.04.063.
9. Заполовський М. Й., Мезенцев М. В., Баленко О. І., Оліфір М. В. **Оптимізаційна модель тягового асинхронного електроприводу дизель-поїзда та її дослідження**. *Системи управління, навігації та зв'язку*. 2023. Вип. 3 (73). С. 45–53. DOI: 10.26906/SUNZ.2023.3.045.
10. Сенченко С. О., Воробйов Б. В., Кириленко Я. О., Ліхно Я. В., Хань Л. **Моделювання режимів буксування асинхронного електроприводу електромобіля**. *Електротехніка та електроенергетика*. 2023. № 4. С. 7–16. DOI: 10.15588/1607-6761-2023-4-1.

- 11.Кривенко С., Гарасьова Н. **Імітаційне моделювання електроприводу вентиляційних систем переробного виробництва.** *Проблеми енергоефективності та автоматизації в промисловості та сільському господарстві* : зб. тез доп. наук.-практ. конф. здобувачів вищої освіти II рівня (магістрів), присвяченої 50-річчю заснування кафедри «Електротехнічних систем та енергетичного менеджменту» ЦНТУ, м. Кропивницький, 24–25 квіт. 2025 р. Кропивницький : ЦНТУ, 2025. С. 17–18.
URL: [Репозитарій ЦНТУ](#) (дата звернення: 23.09.2026).
- 12.Волювач І., Демченко М., Гарасьова Н. **Математична модель відцентрового вентилятора при роботі з частотно-регульованим електроприводом.** *Електротехнічні системи електроспоживання та енергетичний менеджмент* : зб. тез доп. наук. конф. здобувачів вищої освіти II рівня (магістрів) за спеціальністю 141 «Електроенергетика, електротехніка та електромеханіка», м. Кропивницький, 4 груд. 2023 р. Кропивницький : ЦНТУ, 2023. С. 31–33.
URL: [Репозитарій ЦНТУ](#) (дата звернення: 23.09.2026).

Information resources

1. **MathWorks. Induction Motors – Motor Control Reference Examples.** Up-to-date documentation and MATLAB/Simulink examples: scalar control, induction motor parameter estimation, FOC with a speed sensor and sensorless FOC. [MathWorks: Induction Motors](#)
2. **MathWorks. Induction Machine Field-Oriented Control.** Simscape Electrical documentation on implementing FOC in the $d-q$ coordinate system. [MathWorks: Induction Machine Field-Oriented Control](#)
3. **MathWorks. Induction Machine Scalar Control.** A model of the scalar V/f control law for an induction motor. [MathWorks: Induction Machine Scalar Control](#)
4. **MathWorks. Simscape Electrical – Asynchronous Machines.** Up-to-date models of asynchronous motors with short-circuited and phase rotors, parameterisation in SI and relative units. **MathWorks: Asynchronous Machines**