Course guide
205141 - 205141 - Design of Electrical Machines and Actuators

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Unit in charge: Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 709 - DEE - Department of Electrical Engineering.

Degree: MASTER'S DEGREE IN INDUSTRIAL ENGINEERING (Syllabus 2025). (Optional subject).

Academic year: 2026 **ECTS Credits:** 5.0 **Languages:** Catalan

LECTURER

Coordinating lecturer: JUAN MONTAÑA PUIG

Others: DAVID PIEDRAFITA FARRAS
JUAN MONTAÑA PUIG

PRIOR SKILLS

Knowledge of circuit theory.
Knowledge of electrical machines

LEARNING RESULTS

Skills:
S01. Design industrial products, processes, installations and plants.

Competences:
CE1. Design and manage electrical devices (specialisation in Electrical Engineering).

TEACHING METHODOLOGY

The course is organized as follows:

1. Large-group sessions: These sessions include lectures, problem-solving classes, and the assessments corresponding to the first and second examinations.

The instructor will use the teaching approach deemed most appropriate to achieve the learning objectives established for the course. Short activities involving problem-solving, synthesis exercises, and direct questions will also be conducted.

2. Small-group sessions: These sessions are dedicated to laboratory work. A Project-Based Learning (PBL) methodology will be followed, in which students will work on completing the different parts of the project.

In both the large-group and small-group activities, students will be provided at the beginning of the course with a document describing a real electrical machine project. This document will serve as an example during lectures and as a reference for problem-solving exercises and laboratory activities.

LEARNING OBJECTIVES OF THE SUBJECT

At the end of the course, the student will be able to:
·Understand the design methodology of an electrical machine.
·Be able to develop all parts of an electrical machine design project.
·Have the ability to carry out machine designs using computational tools.
·Design electrical machines efficiently.
·Be familiar with the regulations applicable to the design of electrical machines.

STUDY LOAD

Type	Hours	Percentage
Self study	80,0	64.00
Hours small group	15,0	12.00
Hours large group	30,0	24.00

Total learning time: 125 h

CONTENTS

Mòdul 1. Introduction

Description:
In this module, the course and the methodology that will be followed will be presented. A review of the types of electrical machines and their applications will be carried out. Emphasis will be placed on current applications such as electric traction and renewable power generation, which require the continuous redesign of electrical machines.

Once the machines and their applications have been introduced, the different phases that make up the electrical machine design project will be described. Next, the project that will be provided to the student and used as a model throughout the course will be presented in detail.

Finally, the national (UNE-EN) and international (IEC, NEMA) regulatory frameworks governing the design of electrical machines will be presented.

1.1 Course introduction.
1.2 Description of the different types of electrical machines.
1.3 Applications of the different types of electrical machines and the need for their design.
1.4 Description of the electrical machine design project.
1.5 Presentation of the reference project to be used during the course.
1.6 Standards.

Specific objectives:
Learn to identify the different types of machines, their components, and their applications.
Understand the methodology used in the design of electrical machines and the applicable regulations.

Related activities:
Activity 1
Activity 2

Full-or-part-time: 32h
Theory classes: 6h
Laboratory classes: 1h
Self study : 25h

(ENG) Mòdul 2. Design of magnetic circuit

Description:
This module consists of two parts. In the first part, the formulation of electromechanical systems (motors and actuators) will be carried out in order to obtain forces and torques. In the second part, the dimensioning of the magnetic circuit of an electrical machine will be specifically presented.

2.1 Fundamental concepts of magnetism.
2.2 Electromechanical systems: energies, forces, and losses.
2.3 Parts of the magnetic circuit.
2.4 Magnetic circuit excitation (field).
2.5 Flux densities in the different parts of the magnetic circuit.
2.6 Total excitation.
2.7 Permanent magnet machines.

Specific objectives:
-Be able to formulate a magnetic circuit with motion.
-Know how to design each of the different parts of a machine’s magnetic circuit.

Related activities:
Activity 1
Activity 2
Activity 3
Activity 4

Full-or-part-time: 25h
Theory classes: 9h
Laboratory classes: 4h
Self study : 12h

Module 3. Electrical circuit design

Description:
In this module, the calculation method for sizing the electrical circuit of an electrical machine will be presented. Different types of windings will be studied.

3.1 Introduction to the electrical circuit.
3.2 Design of windings.
3.3 Other elements of the electrical circuit.

Specific objectives:
-Know how to design the windings of an electrical machine.
-Understand the effects on the magnetic flux distribution of different winding designs.

Full-or-part-time: 19h
Theory classes: 3h
Laboratory classes: 4h
Self study : 12h

Mòdul 4. Electrical insulation design

Description:
To ensure the dielectric insulation of the conductors, the insulating materials must be properly sized.

4.1 Introduction.
4.2 Dielectric breakdown.
4.3 Insulation materials used in electrical machines.
4.4 Sizing of dielectric insulation.
4.5 Dielectric insulation and partial discharge tests.

Specific objectives:
-Understand the process of dielectric breakdown in insulators.
-Know how to design the insulation of the conductors in electrical machines.

Related activities:
Activity 1
Activity 2
Activity 3
Activity 5

Full-or-part-time: 19h
Theory classes: 4h
Laboratory classes: 4h
Self study : 11h

Mòdul 5. Thermal design

Description:
Although the efficiency of electrical machines is high, there is still some heat generation that must be considered in the machine design. This module summarizes the process for calculating the thermal circuit of electrical machines.

5.1 Introduction
5.2 Heat generation and dissipation.
5.3 Thermal conduction in conductors.
5.4 Thermal conduction in the machine laminations.
5.5 Convection and radiation.
5.6 Cooling systems of electrical machines.
5.7 Tests

Specific objectives:
-Understand the origin of heat generation in electrical machines.
-Identify the heat transfer processes in electrical machines.
-Design the thermal system of electrical machines.

Related activities:
Activity 1
Activity 3
Activity 5

Full-or-part-time: 13h
Theory classes: 3h
Self study : 10h

Module 6. Parametric design

Description:
In this module, the method of parametric design will be presented. Through the derived expressions, the overall dimensions of an electrical machine can be obtained from its specifications. Direct current machines and alternating current machines will be treated separately. Finally, conclusions will be discussed regarding machine size, thermal significance, and the concept of similarity.

6.1 Introduction to parametric design.
6.2 Parametric expressions for direct current machines.
6.3 Parametric expressions for alternating current machines.
6.4 Parametric expressions for transformers.
6.5 Conclusions of parametric design.

Specific objectives:
Be able to obtain the overall dimensions of a machine from its specifications.
Be able to obtain the general specifications of a machine from its dimensions.

Related activities:
Activity 1
Activity 2
Activity 3
Activity 4

Full-or-part-time: 17h
Theory classes: 5h
Laboratory classes: 2h
Self study : 10h

ACTIVITIES

ACTIVITY 1

Description:
In-person classes (large group) where the main contents of the course will be delivered.
In some sessions, in-class exercises will be carried out, either individually or in small groups.

Specific objectives:
To transfer the necessary knowledge for a correct interpretation of the content developed in large-group sessions, to resolve doubts related to the course syllabus, and to develop specific competencies.
Development of general competencies.

Material:
Course lecture notes.
Reference project provided.
Recommended course bibliography.

Delivery:
There are no specific submissions for this activity.

Full-or-part-time: 56h
Theory classes: 26h
Self study: 30h

ACTIVITY 2: LABORATORY AND SIMULATION PRACTICAL ACTIVITIES

Description:
Laboratory and simulation activities.

Workshop 1 and 2 (laboratory): Types of machines and their structural components.
Workshop 3 (computer aided design): Introduction to finite element software for the design of electrical machines.
Workshop 4, 5, and 6 (computer aided design): Design of an electrical machine or different types of machines using finite elements.

Specific objectives:
-Be able to identify the different types of machines and their structural components.
-Ability to design an electrical machine using software based on the finite element method.

Material:
-Lab manuals.
-Software.

Delivery:
Submissions associated with each practical session.

Full-or-part-time: 25h
Laboratory classes: 15h
Self study: 10h

ACTIVITY 3: EXERCISES AND SMALL PROJECT(S)

Description:
Exercises: Exercises will be provided, organized according to the theoretical teaching units, along with their corresponding numerical solutions, so that students can work autonomously and validate their results. Articles will also be proposed for analysis and problem-solving. Some assessable exercises will be carried out in class.

Additionally, a small project on the design of an electrical machine will be proposed.

Specific objectives:
The objective of this activity is to motivate students to keep up with the course as a way of consolidating knowledge and mastering the concepts in a clear and solid manner that will allow them to achieve a satisfactory level. The student must be able to analyze the situation presented in the statement, structure the available information to formulate the problem, and solve it using the knowledge acquired.

Material:
Statements of the applied activities.

Delivery:
At the end of each topic, exercises will be submitted according to the course schedule.
Exercises carried out during the sessions will be collected by the lecturer.
Submission of the small project.

Full-or-part-time: 40h
Self study: 40h

ACTIVITY 4: TEST 1

Description:
Test corresponding to the contents of the first half of the course.
The assessment weight of this test is 35% of the course grade.

Specific objectives:
The test must demonstrate that the student has acquired and assimilated the knowledge from modules 1, 2, and part of 3.

Material:
Test statement.

Delivery:
Test statement with its answers.

Full-or-part-time: 2h
Theory classes: 2h

ACTIVITY 5: TEST 2

Description:
Test corresponding to the contents of the second half of the course.
The assessment weight of this test is 35% of the course grade.

Specific objectives:
The test must demonstrate that the student has acquired and assimilated the knowledge from modules 3, 4, 5 and 6.

Material:
Test statement.

Delivery:
Test statement with its answers.

Full-or-part-time: 2h
Theory classes: 2h

GRADING SYSTEM

The final course grade (100%) is determined by the following assessment activities:

35% – Test 1 (Activity 4)
35% – Test 2 (Activity 5)
10% – Exercises/Classroom activities/Small project/s (Activity 3)
20% – Laboratory work (Activity 2)

Unsatisfactory results in Test 1 (Activity 4) may be rataked through a written examination to be held on the date scheduled for the final examination, during which Test 2 (Activity 5) is also conducted. All enrolled students who obtained a grade below 5.0 in Test 1 are eligible to retake this examination. If the grade obtained in the retake examination is 5.0 or higher, the original Test 1 grade will be replaced by a grade of 5.0 points. If the grade obtained is below 5.0 points, it will replace the original grade only if it is higher than the previous one.

Students who meet the eligibility requirements and retake the reassessment examination, they will have the reassessment grade replace the grades of Test 1 and Test 2. Grades of Activity 3 and 2 will be retained.

If the final grade obtained in the reassessment examination is below 5.0, it will replace the original grade only if it is higher than the previous one. If the final reassessment grade is 5.0 or higher, the final course grade will be recorded as a passing grade of 5.0.

EXAMINATION RULES.

The rules will be announced before each assessment.

BIBLIOGRAPHY

Basic:
- Corrales Martín, J. Cálculo industrial de máquinas eléctricas. Barcelona: Marcombo Boixareu, 1982. ISBN 8426704387.
- Corrales Martín, J. Cálculo modular de máquinas eléctricas: manual práctico. Barcelona: Marcombo Boixareu, 1994. ISBN 8426709850.
- Pyrhónen, J.; Jokinen, T.; Hrabovcová, V. Design of rotating electrical machines. Chichester: John Wiley & Sons, 2008. ISBN 9780470695166.

Complementary:
- Hameyer, K.; Belmans, R. Numerical modelling and design of electrical machines and devices. Southampton [etc.]: Wit Press, 1999. ISBN 1853126268.
- Corrales Martín, J. Cálculo óptimo de transformadores. Barcelona: UPB. ETSIIB: Marcombo, 1977. ISBN 8460010260.
- Hamdi, Essam S. Design of small electrical machines. Chichester [etc.]: John Wiley & Sons, 1994. ISBN 0471952028.

RESOURCES

Other resources:
-Documentation from the ABB and AEG collections of the Terrassa Campus Library (UPC).
-Martínez Barrios, Luis. Course lecture notes (Department of Electrical Engineering).
-Montañá Puig, Joan. Course lecture notes (Department of Electrical Engineering).
-Piedrafita Farras, David. Course lecture notes (Department of Electrical Engineering).