# NATIONAL UNIVERSITY OF ENGINEERING

## COLLEGE OF ELECTRICAL AND ELECTRONICS ENGINEERING

## ELECTRICAL ENGINEERING PROGRAM

# EE211 – ELECTRICAL MACHINES I

## I. GENERAL INFORMATION

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| **CODE** | **:** | EE211 – Electrical Machines I |
| **SEMESTER** | **:** | 6 |
| **CREDITS** | **:** | 05 |
| **HOURS PER WEEK** | **:** | 07 (Theory – Practice) |
| **PREREQUISITES** | **:** | EE112, FI463 |
| **CONDITION** | **:** | Mandatory |

## II. COURSE DESCRIPTION

This course involves the following topics: Magnetic circuits. Iron core reactor. Transformers and autotransformers. Transformers in three-phase systems. Conversion of electromechanical energy. Magnetomotive force, magnetic field, spatial vector, electromotive force and torque in electric machines.

## III. COURSE OUTCOMES

General outcomes:
At the end of the course the student will:

- Have the theoretical knowledge to the student about the magnetic circuits, the steady-state operation of the single-phase and three-phase transformer, the basic principles of electric machines and the conversion of electromechanical energy.

## IV. LEARNING UNITS

### 1. MAGNETIC CIRCUITS

Introduction. Magnetic properties of matter. Magnetization feature Mathematical models Configuration of magnetic circuits. Resistive analog circuit. Ampere circuit law. Continuity of magnetic flux lines. Excitation with direct current. Solution methods Graphic method. Iterative method. Excitation with alternating current. Hysteresis losses and Foucault losses. Reactor with iron core. Equivalent circuit Parameter determination.

### 2. TRANSFORMERS - AUTOTRANSFORMERS.

Iron core transformers. Concept, types and characteristics. Ideal transformer. Variables and impedances reflected. Determination of equivalent circuits. Determination of parameters from the short circuit and open circuit tests. Phasorial diagram with different types of loads: resistive, inductive and capacitive. Test under load and additional tests. Operation of transformers under load. Determination of efficiency and regulation. Transformers with taps, regulation without load and under load. Heating and noise in transformers. Unit Analysis Autotransformer, concept, types, equivalent circuits, losses. Advantages and disadvantages.

3. **TRANSFORMERS IN THREE-PHASE SYSTEMS**
   Connection types, Delta-star, Delta-delta, Star-delta, Star-star, Zig-zag and Delta open. Zero impedance concept. Connection groups, hourly rates, experimental determination of hourly rates. Parallelization of equality transformers and different types and groups of connections. Power distribution for load sharing with equality and different transformation relationships. Three winding transformers, equivalent circuit.

4. **ELECTROMECHANICAL ENERGY CONVERSION**
   Electrical and mechanical systems, pure elements, state variables and energy status functions. Mechanical force or torque of electrical origin from the principles of virtual works. Single-double-multiple excitation systems. Electromechanical, electromagnetic dynamics, system parameters, equations of rotation and translation movement.

5. **FORCE MAGNETOMOTRIZ, MAGNETIC FIELD, ELECTRIC FORCE AND TORQUE IN THE ELECTRICAL MACHINES**
   Magnetomotive force (MF) created by an experimental full-pass coil, magnetomotive force of a cut-off coil. MF of a group of coils and harmonic analysis. Space vector concept. Passage and distribution factors. Winding factor, equivalent winding. Production of rotating Magnetomotive Forces. Harmonic Analysis Magnetic field in an electric machine. Electromotive force (emf). Torque in electric machines.

## V. METHODOLOGY

The teaching methodology of the course is based on:

- Theoretical lectures according to the scheduled content of the course
- Practical classes aimed at solving exercises and proposed problems.
- Qualified classroom practices on the content of theory classes and directed practices.

## VI. EVALUATION FORMULA

The learning will be evaluated the following way:

- Partial Exam (PE): Weight 1
- Final Exam (FE): Weight 1
- Average of Practices (P): Weight 1

$$FA = \frac{PE + FE + P}{3}$$

## VII. BIBLIOGRAPHY


- MIT- Massachusetts Institute of Technology, Magnetic Circuits and Transformers.
- Gourizhankar, Electromechanical Energy Conversion.
- A.E. Fitzgerald - Charler Kingsley and A. Kusko ¨Electric Machinery¨
- Enrique Ras Oliva ¨ Transformers¨.
- Kostenko, ¨ Electric Machines ¨

- Jerome Meisel ¨ Principles of Electromechanical Energy Conversion¨.McGraw - Hill. 1969
- P.C. Sen. ¨Principles of Electric Machines and Power Electronics¨. Second Edition John Wiley & Sons. 1997
- Charles V. Jones ¨The Unified Theory of Electrical Machines¨. Butterworth & Co. 1967.
- Che - Mun Ong. ¨Dynamic Simulation of Electric Machinery. Using Matlab / Simulink¨. Printice Hall PTR. 1998
- David C. White and Herbert H. Woodson. ¨ Electromechanical Energy Conversion ¨. John Wiley & Sons, Inc. 1959.