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Acronyms and Abbreviations

CEEECoM	Capacity Enhancement in Electrical Equipment Condition Monitoring and Fault Diagnostics
HEI	Higher Education Institution

Aalto University TAL TECH Royal University of Bhutan

CEEECoM WP No:	WP5
CEEECoM partner HEI	Jigme Namgyel Engineering College (JNEC) – RUB
Course Title:	AC Machines
Course Code:	EMD204
Course Level	UG/Year II/Semester II
ECTS Credits:	**6**
Programme & Module requirement:	Undergraduates in Electrical Engineering – Compulsory
Course Status:	To be modified and offered
Credit:	12
Course Coordinator:	Chenga Dorji
Course Teacher(s):	Chenga Dorji/Jagat Bdr. Ghalley/Karchung

Course Objective and Outline:

This module will develop fundamental concepts: construction, principles of operation, application, and the basic analytical understanding of various types of AC machines. This module will also equip the student with basic experimental skills for operation, troubleshooting, and maintenance of AC machines.

LO1: Identify the applications of synchronous machines, induction machines, split-phase motors, universal motors, and reluctance motors.

LO2: Analyze the construction and working principle of synchronous machines, induction machines, split-phase motors, universal motors, and reluctance motors.

LO3: Classify AC machines based on the number of phases, rotating field or armature, type of prime mover, machine speed, and rotor type.

LO4: Enumerate the advantage of the rotating field in high-rating synchronous machines.

LO5: Analyze armature reaction effects for unity, lagging, and leading power factors, and assess their impact on terminal voltage and load current.

LO6: Calculate voltage regulation using synchronous impedance and AT methods.

LO7: Operate and synchronize three-phase alternators in parallel.

LO8: Evaluate the influence of supply voltage changes on starting torque, load torque, slip, and line current for an inductor motor.

LO9: Select an appropriate starter for a specific machine and calculate starting current using Direct-On-Line (DOL) starters and other variants.

LO10: Assess the suitability of electrical machines for specific applications, employing critical evaluation.

LO11: Diagnose, troubleshoot, and perform maintenance on AC machines effectively.

Module Delivery Method:

☒ Face-to Face
☒ Blended
☐ Fully Online

Pre-requisites:

EMD102: DC Machines and Transformer

Co-requisites:
NA

Learning and teaching approach

Type	Approach	Hours per week	Total credit hour
Contact	Lecture	3	**105**
	Class Exercise/presentation	1	
	Practical	3	
Independent Study	Written assignment/ self – study	1	**15**
Total		**8**	**120**

Assessment Approach

Assessment will be carried out on a continuous basis through the following assessment and a semester end examination: -

A. Assignment: 15%

Component 1: Numerical Problem-Solving Assignment – 5%
Each student will complete a minimum of one assignment focusing on numerical problem-solving within the subject matter. The assignment details will be communicated by the module tutor. Assignments will be evaluated based on accuracy, interpretation, evidence of progress, writing style, and timely submission, each contributing to a total of 15%. The assignment will be marked out of 5 marks as follows.

Accuracy of Information/Numerical Problems: 2 marks
Interpretation/Analysis: 1 mark
Evidence of Progress: 1 mark
Overall Effectiveness of Writing Style: 0.5 marks
Timely Submission: 0.5 marks

Component 2: Presentation on AC Machine-related Topic – 10%
Students will undertake at least one presentation on a topic related to AC machines, aligning with the subject matter's operation, troubleshooting, and maintenance. The module tutor will provide guidance on presentation themes. Assessment criteria include content accuracy, analysis, progress demonstration, presentation quality, and punctual submission. This component will be marked of 10 as follows:

Content Accuracy: 3 marks
Analysis and interpretation: 2.5 marks
Presentation Quality: 2.5 marks
Evidence of Progress: 1.5 marks
Timely Submission: 0.5 marks

B. Phase Test: 10%

Students will sit for the scheduled Phase Test (Paper Based – Closed book) which is 10% of the total

weightage. The phase test will cover the syllabus coverage a week before the schedule of the test and will test at least 40% of the learning outcomes. The phase test will be centrally organized and conducted by the exam cell for a duration of an hour. Generally, it will be conducted between 6th and 7th week after the start of the semester.

C. Practical: 35%

The assessment of practical works will be a continuous process which comprises (laboratory works: 5 marks, laboratory reports: 5 marks, practical exam: and Viva-Voce. The assessment of practical will be done by the module tutor.

Laboratory works: 10%

The module tutor and laboratory technician will observe the student's laboratory works. Based on the students' performance, they will be assessed. Each entry will be marked out of 10 marks based on the following criteria and then converted to 10%: -

Compliance with the safety measures – 2 marks
Response to the questions related to the practical – 3 marks
Circuit connection as per the circuit diagram – 2 marks
Ability to perform the practical – 3 marks

Laboratory report: 5%

Each student will write the laboratory report for the practical performed and submit before commencement of next practical class after analysing and interpreting the results. Students are expected to write the report as per the laboratory manual circulated by the tutor before coming to the lab class and will carry out the practical as per the procedure during the practical hours and take note of all the observations during the class. They will use the readings and analyse and interpret the results and submit before the conducting next practical.

The assessment and evaluation of the laboratory report will be based on:

Presentation and interpretation of result – 2.5 marks
Format, correct sequencing of materials as (aim and objective(s), materials required, theory, procedure, precaution, and conclusion), neatness, and language. – 2 marks
Timely submission – 0.5 mark

Practical Test /skills test/ exams: 10%

Students will have to sit for the practical test after completing all the practical. The exam or test will be conducted by the module tutor in collaboration with the Lab Technician. This assessment will be done individually towards 12th or 13th week after the commencement of the semester.

The assessment and evaluation of the practical test will be based on:

Brief theory – 1 mark
Circuit diagram – 2 marks
Specification of apparatus required – 1 mark
Observation table, calculation and graphs (if any) – 2 marks
Connection – 2 marks
Interpretation of results – 2 marks

Viva- voce: 10%

Students will sit for the viva-voce. This component will help to test students' learning in a face-to-face mode by the internal examiner nominated by the Programme Leader. This component will build communication skills by sitting in a face-to-face mode with the faculties of the department not teaching the module.

D. Semester-end Examination: 40%

The Semester End Examination will be conducted at the end of the semester which will be 40% of the total weightage. It will be paper based-closed book for 3 hours.

Overview of the assessment approaches and weighting

Areas of Assessment	Quantity	Weighting (%)
A. Assignments	2	15
B. Phase Test	1	10
C. Practical	9	35
D. Semester-end Examination	1	40
Total		**100**

Module Syllabus:

Lectures:

Contents

Unit I: Alternators

1.1 Definition and classification
1.2 Constructional details of synchronous machines
1.3 Constructional and operational features of salient pole and cylindrical rotors
1.4 Working principle of an alternator
1.5 AC Armature winding and its types
1.6 EMF equation
1.7 Effects of armature reaction, armature resistance, leakage reactance, synchronous reactance, synchronous impedance (R, X and Z)
1.8 Alternator on no (without) load and alternator on (with) load and draw phasor diagram for unity power factor, leading and lagging power factor.
1.9 Effect of variation of p.f on terminal voltage
1.10 Voltage regulation and methods of finding voltage regulation.
1.11 Two Reactance concepts for Salient pole machines, Power developed in Alternator, Power/Power angle characteristics, V-curve for alternator.
1.12 Losses and Efficiency of Alternator

Unit II: Parallel Operation of Alternators

2.1 Parallel operation of single phase and three phase alternators, advantages, and conditions.
2.2 Synchronous current, power, and torque.
2.3 Effect of increasing the driving torque, excitation, speed, voltage of one alternator on the other
2.4 Load sharing between two alternators.

2.5 Synchronizing with infinite bus

Unit III: Synchronous Motors

3.1 Working principle of synchronous motor.
3.2 Starting methods.
3.3 Synchronous condenser.
3.4 V-curve of synchronous motor.
3.5 Merits and demerits of synchronous motor and applications.

Unit IV:-Induction Motor

4.1 Rotating magnetic fields
4.2 Constructional detail of wound rotor and cage rotor induction motor
4.3 Concept of slip, rotor current and emf, rotor torque, starting torque, maximum torque, and rotor emf frequency
4.4 Torque speed and torque slip curves
4.5 Effect of change in supply voltage on starting torque
4.6 Power flow, losses, and efficiency, the effect of loading (no load to full load) in an Induction Motor on its power factor
4.7 Open circuit and blocked rotor tests and circle diagram
4.8 Speed Control of Induction Motor
4.9 Equivalent circuit and vector diagram.
4.10 Application of squirrel cage and wound rotor three-phase induction motor
4.11 Introduction to induction generator

Unit V: Special Case Motors

5.1 Construction, operating principle, characteristics of capacitor phase split (Capacitor start, run, and permanent), shaded pole.
5.2 Constructional details, working principle and characteristic of universal motor, repulsion motors, reluctance motor and hysteresis motor and application of these motors.
5.3 Methods of reversing the direction of rotation, applications, commutation and their remedies of single-phase motors.
5.4 DC series motor as AC series motor.

Unit VI: Common faults and troubleshooting of AC Machines

6.1 Causes of faults and fault diagnosis in an induction machine and synchronous machines.
6.2 Common faults, troubleshooting methods and maintenance in alternator
6.3 Common faults, troubleshooting methods and maintenance in induction motor
6.4 Common faults, troubleshooting methods and maintenance in synchronous motor.

List of Practical (s)

1. To perform open circuit test and short circuit test of synchronous generator and determine the voltage regulation using E.M.F method and M.M.F method.
2. To demonstrate the synchronization of three phase synchronous generators using (a) three dark lamp method (b) two bright and one dark lamp method (c) Synchroscope method.

3. To start, run and demonstrate the concept of magnetic locking in three phase synchronous motor.
4. To measure the slip of three phase induction motor (a) by measuring speed using Tachometer (b) by measuring rotor current frequency by galvanometer method (c) Stroboscope method.
5. To perform no load and blocked rotor test on three-phase induction motor and draw the circle diagram.
6. To start the three-phase induction motor using different starters, run, load and determine the efficiency of the induction motor.
7. To perform the load test on three phase induction motor and determine the power factors at different percentage of loading.
8. To perform the speed control of three phase induction motor using (a) voltage control method (b) rotor resistance control method for slip ring induction motor.
9. Start and run capacitor split phase induction motor and start, run and reverse ac series motor.
10. Speed control of induction motor using software

Note: Virtual labs will be initiated as and when required and feasible**.**

Reading List:

Essential Reading

Bhattacharya, S. K. (2012*). Electrical machines*. Tata McGraw-Hill Publishing Company Limited.

Bhimbra, P S. (2014). *Electrical machinery*. Khanna Publishers.

Electrical is easy. (2018, February 12). *AC Machinery fundamentals (Lecture series)* [Video]. YouTube. https://www.youtube.com/watch?v=RX5Xj1keQIc&list=PLPpCFgQP7QKEA0Mi9WKW_ywa0wIqx-2-w

Gonen, T. (2012). *Electrical machines with MATLAB.* CRC Press, Taylor and Francis Group.

Gupta, J.B. (2015). *Theory and performance of electrical machines.* S K Kataria and Sons.

Guru, B.G., & Hiziroglu, H.R. (2007). *Electric machinery and transformer.* Oxford University Press.

Additional Reading

Gross, C.A. (2007). *Electric machines*. CRC Press, Taylor and Francis Group.

Harlow,J.H. (2012). *Electric power transformer engineering.* CRC Press, Taylor and Francis Group.

Kosow, I.L. (2007). *Electric machinery and transformers.* Prentice Hall of India Private Limited.

Kothari, D.P., & Nagrath, I.J. (2010). *Electric machines*. Tata McGraw-Hill Publishing Company Limited.

Mehta, V.K., & Mehta, R. (2006). *Principles of electrical machines*. S.Chand & Company Limited.

Note: %modification in course content is 5%