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Related Work Package	WP5: Curriculum Enhancement
Related Task(s)	T2.4 Syllabus modernization and development
Lead Organization	KU

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:	Condition Monitoring and Fault Diagnostic Techniques in Electrical Equipment
Course Code:	EMC406
Course Level	UG/Year IV/Semester VIII
ECTS Credits:	**6**
Programme & Module requirement:	Bachelor of Engineering in Power Engineering - Elective
Course Status:	To be developed and offered
Credit:	12
Course Coordinator:	Chenga Dorji
Course Teacher(s):	Chenga Dorji/Jagat Bdr. Ghalley/Karchung

Course Objective and Outline:

This course intends to provide an understanding of the principles and applications of condition monitoring in anomaly detection and fault diagnosis of electrical machines. The course will cover trend in machine maintenance, electro-mechanical behavior of normal and faulty machines, visual inspection techniques, condition monitoring through sensors, fault diagnosis, non-destructive testing of machines, and computer based maintenance management. The course will also have embedded computer based fault simulation and maintenance management demonstrations.

Learning Outcomes:

On completion of the course, students will be able to:

L01. Explain different types of faults occurring and electrical machines and the consequence of equipment failures in industries and utilities

L02. Demonstrate the technique related to the health monitoring of electrical equipment including different methods, sensors, data acquisition systems, etc.

L03. Explain the conventional as well as recent trend in technologies related to the health monitoring and fault diagnostics of electrical machines.

L04. Simulate and analyze different faults occurring in electrical equipment like motors, generators and transformers.

L05. Utilize different types of maintenance and maintenance strategies in practice

Module Delivery Method:

☒ Face-to Face
☒ Blended
☐ Fully Online

Pre-requisites:

EMC203: D. C Machines and Transformers

EMC204: A.C Machines.

Co-requisites:

NA

Learning and teaching approach

Type	Approach	Hours per week	Total credit hours
Contact	Lecture	3	**105**
	Class exercise and presentation	1	
	Practical	3	
Independent study	Written assignment/self – study/VLE discussion	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 %

Each student will write a minimum of two assignments that will cover the overall concept of the module. The assignment could be numerical based/ case study/ research based etc. on any of the following areas:

- Condition monitoring and fault diagnostic.
- Application of IoT in condition monitoring and fault diagnostic.
- Numerical/analysis related to fault diagnostic and condition monitoring.

Each entry will be marked out of 10 marks based on the following criteria:

For theory-based assignments:

Accuracy of information/accuracy of the numerical problems – 8 marks
Clarity of Opinion – 5 marks
Overall effectiveness of writing style – 1 mark
Timely submission – 1 mark

For numerical based Assignment.

Method of approach to the question – 7 marks
Choosing the right approaches – 4 marks
Showing detail steps in solving the problem – 1 mark
Accuracy to the solution – 2 marks
Timely submission – 1 mark

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 whatever is the syllabus coverage a week before and it will test at least 40 % of learning outcomes.

C. Practical: 25 % [Laboratory work: 10 marks, Laboratory report: 5 marks, Practical exam: 10 marks, Viva-voce: 10 marks]

The assessment of practical works will be a continuous process. The assessment of practical will be done by the module tutor and by the internal moderation team appointed by Programme Leader.

Laboratory works: **10 %**

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

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.

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: **5 %**

Students will 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 can either be done individually or in groups.

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

Brief theory – 1 mark
Circuit diagram – 1 mark
Observation table and calculation – 1 mark
Interpretation of results – 2 marks

Viva- voce: **5 %**

Students will sit for the viva-voce. This component will help to test students learning in face-to-face by internal examiner nominated by Head of the Department (HoD). This component will also help students to build communication skills by sitting face-to-face with the faculties of the department who is not teaching that module.

D. End Semester Examination: **50 %**

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, 3 Hours duration. This will include all the learning outcomes, and question may include,

- Defining terminologies
- Stating application
- Analysing and solving numerical problems
- Designing circuits

Overview of the assessment approaches and weighting

Areas of Assessment	Quantity	Weighting (%)
A. Assignments	2	15
B. Phase Test	1	10
C. Practical	4	25

D. Semester End Exam	1	50
Total		**100**

Module Syllabus:

Lectures:

Contents

Unit 1: Overview of Electrical Machines Use and Maintenance (3 Hours)

Learning Outcomes: LO1

Application of electrical machines in industries and utilities such as processing industry, power plants, transports, etc.; Consequences of equipment failures; Techniques to avoid failure of machines; Breakdown versus condition-based-maintenance.

Unit 2: Introduction to Condition Monitoring: (4 hours)

Learning Outcomes: L02

Condition monitoring overview and purpose; Common condition monitoring techniques; Invasive and non-invasive methods; Sensors, data acquisition, and overview of signal pre-processing for condition monitoring.

Unit 3: Faults in Transformers and Diagnosis (12L + 4P hours)

Learning Outcomes: LO3, L04

Review of Transformer Construction and Operation, Behavior of Normal Transformer, Transformer Condition Indicators

Insulation Classes, Cooling Systems, Thermal performance of transformers: heating at constant load, heating under variable load, insulation wear and load capacity, overload;

Transformer faults: main causes, core faults, winding faults, switching failures, tanks fault, other failures;

Transformer testing and fault diagnostics: HVPD tests, Acoustic detection, short-circuit and open-circuit impedance measurement, frequency-response analysis, Polarization index, measurement of DC resistance, tan-delta tests, Dissolved Gas Analysis;

Fault simulation exercise and laboratory demonstration

Unit 4: Faults in Rotating Machines and Diagnosis (16 L + 6 P hours)

Learning Outcomes: LO3, L04

Review of Machine Construction and Operation, Behavior of Normal Machines, Machine Condition Indicators

Electrical Faults: Symmetrical Faults, Asymmetrical faults, Unbalance supply voltage, Over voltage, Phase reversal, Overload Stator Short Circuit, Broken Rotor Bars and End-ring faults

Mechanical Faults: Airgap Eccentricity: Static, Elliptical, Dynamic and Mixed Eccentricity, Bearings Damage

Machine Testing and Fault Diagnostics: Fault Indicators and Fault Representing Equations

Bearing Currents and it's diagnosis: Indirect methods: Vibration, ultrasonic detection, and direct

methods: voltage measurement, Rogowski Coil; Reduction of bearing currents: Insulated bearings, conductive greases, shaft grounding contacts and rings, characteristics regulation of frequency converters
Diagnostics of stator and rotor faults: power electronics, local and global sizes, how the fault starts, methods of diagnostics: side harmonics, magnetic flux density distribution, Park-Clarke Vector, winding control, insulation, measurement of insulation resistance,
Fault simulation exercise and laboratory demonstration

Unit 5: Condition Monitoring and Condition Based Maintenance (10L + 5P hours)
Learning Outcomes: LO3, L04, LO5
Types of Maintenance: Breakdown vs. Condition Based Maintenance; Scheduled, Preventive and Predictive maintenance;
Condition monitoring and signal processing for state of health and fault indications.
Recent Trend in Condition Based Maintenance: Remote sensing and cloud based monitoring and maintenance management : Internet of Things (IoT), IoT Based Sensing,
Application of Machine Learning and Artificial Intelligence for Maintenance, Use of trained models for anomaly detection and fault diagnosis.
Commercial CMMS (Cloud/computer based maintenance management system), CMMS Architecture and Interface, Use of CMMS

Lab Simulation Tutorials and Demonstration:
1. Simulation of common motor faults like eccentricity and stator winding fault and motor current signature analysis
2. Thermal analysis of machines for healthy and faulty cases
3. Demonstration of Soft-foot fault and vibration and current signature analysis

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Textbook/Refrence/Reading List / Indicative resources:

1. B.K.N. Rao, “Handbook of Condition Monitoring”, Elsevier Science; 1st ed edition (December 6, 1996)
2. Course Handouts/Manuals
3. Latest publications on the related topics

4. Hamid A.Toliyat, Subhasis Nandi, Seungdeog Choi, Homayoun Meshgin Kelk (2013), *Electric Machines: Modelling, condition monitoring, and Fault Diagnosis.* Taylor & Francis, CRC Press.

5. Irfan, M (2019), *Advanced Condition Monitoring and Fault Diagnosis of Electric Machines.* IGI Global.