

**EE456: CONDITION MONITORING OF ELECTRICAL EQUIPMENTS**  
**CREDITS = 3 (L=3, T=0, P=0)**

**Course Objective:**

This course will enable the students to acquire basic skills of condition monitoring and diagnostic techniques of electrical equipment's.

**Teaching and Assessment Scheme:**

Teaching Scheme			Credits	Marks Distribution				Total Marks
L	T	P		Theory Marks		Practical Marks		
			ESE	CE	ESE	CE		
3	0	0	3	70	30	30	20	150

**Course Content:**

Unit No.	Topics	Teaching Hrs.
1	<p><b><u>Introduction:</u></b></p> <p>Review of Today's Industry and Role of Condition Monitoring.</p>	01
2	<p><b><u>Maintenance Management and Applied Strategies:</u></b></p> <p>Maintenance Management Systems, Basic Principals of Maintenance Strategies – Preventive Maintenance, Predictive Maintenance, Proactive Maintenance, Reliability Centered Maintenance, Total Productive Maintenance. Structure of the Maintenance Management System – Maintenance Objectives, Assets Management, Human Resources in Maintenance, Spare Parts Management, Determination of Maintenance (Strategy) Per Equipment.</p>	03
3	<p><b><u>Condition Monitoring and Diagnostics of Transformer:</u></b></p> <p>Introduction, Transformer Diagnostics, Transformer Maintenance and Power Plant Rehabilitation.</p> <p><b>Dissolved Gas Analysis</b> – Background, Transformer Diagnosis Using Individual and Total Dissolved Key Gas Concentrations, Diagnosing a Transformer Problem Using Dissolved Gas Analysis and the Duval Triangle, Expertise Needed.</p> <p><b>Oil Physical / Chemical Tests</b> – Transformer Oil Tests that should be performed annually with the Dissolved Gas Analysis, Dielectric Strength, Interfacial Tension (IFT), Acid Number, Furans, Oxygen, Oxygen Inhibitor, Oil Power Factor, Moisture.</p> <p><b>Age Test on Insulation</b> – Insulation Power Factor Test, Capacitance Tests, Excitation Current Test, Bushing Tests, Percentage Impedance / Leakage Reactance Test, Sweep Frequency Response Analysis Tests.</p> <p><b>Visual Inspection</b> – Background, Temperature Indicators Online, Temperature Indicators Offline, Conservator, Conservator Breather, Nitrogen, Oil Leaks, Pressure Relief Device, Oil Pumps, Fans and Radiators, Buchholz Relay, Bladder Failure Relay.</p>	15

## **Infrared Temperature Analysis:**

IR for Transformer Tanks, IR for Surge Arresters, IR for Bushings, IR for Radiators and Cooling Systems.

### **Corona Scope Scan**

**Ultrasonic and Sonic Fault Detection** – Background, Process.

**Vibration Analysis** – Background.

**Turns Ratio Test** – Background, Process.

**DC Winding Resistance Measurement** – Background, Process.

**Core Insulation Resistance and Inadvertent Core Ground Test** – Background, Process.

**Estimate of Paper Deterioration (Online)** – CO<sub>2</sub> and CO Accumulated Total Gas Values, CO<sub>2</sub>/CO Ratio, and Furans.

**Estimate of Paper Deterioration (Offline During Internal Inspection)** – Degree of Polymerization (DP), Background, Process.

**Internal Inspection** – Background.

### **Transformer Borescope**

**Transformer Operating History** – Background

**Transformer Diagnostics / Condition Assessment Summary.**

## 4 **Condition Monitoring of Rotating Electrical Machines:**

24

**Construction, operation and failure modes of electrical machines** – Introduction, Materials and temperature, Construction of electrical machines – General, Stator and frame, Rotors, Windings, Enclosures, Connections, Summary.

Structure of electrical machines and their types, Machine specification and failure modes, Insulation ageing mechanism – General, Thermal ageing, Electrical ageing, Mechanical Ageing, Environmental ageing, Synergism between ageing stresses. Insulation Failure modes – General, Stator winding insulation, Stator winding faults, Rotor winding faults. Other failure modes – Stator core faults, Connection faults (High-voltage motors and generators), Water coolant faults (all machines), Bearing faults, Shaft voltages. Conclusion.

**Instrumentation requirements** – Introduction, Temperature measurement, Vibration measurement – General, Displacement transducers, Velocity transducers, Accelerometers. Force and torque measurement, Electrical and magnetic measurement, Wear and debris measurement, Signal conditioning, Data acquisition Conclusion.

**Temperature Monitoring** – Introduction, Local temperature measurement, Hot-spot measurement and thermal images, Bulk measurement, conclusion.

**Vibration monitoring** – Introduction, Stator core response – General, Calculation of natural modes, Stator electromagnetic force wave. Stator end-winding response, Rotor response – Transverse response, Torsional response. Bearing response – General, Rolling element bearings, Sleeve bearings. Monitoring techniques – Overall level monitoring, Frequency spectrum monitoring, Faults detectable from the stator force wave, Torsional oscillation monitoring, Shock pulse monitoring. Conclusion.

### **Electrical techniques: current, flux and power monitoring**

Introduction, Generator and motor stator faults – Generator stator winding fault detection, Stator current monitoring for stator faults, Brushgear fault detection, Rotor-mounted search coils. Generator rotor faults – General, Earth leakage faults on-line, and Turn-to-turn and earth leakage faults off-line. Motor rotor faults – General, Airgap search coils, Stator current monitoring for rotor faults, Rotor current monitoring. Generator and motor comprehensive methods – General,

Shaft flux, Stator current, Power, Shaft voltage or current, Mechanical and electrical interaction. Effects of variable speed operation, conclusion.

**Condition-based maintenance and asset management:**

Introduction, Condition-based maintenance, Life-cycle costing, Asset management, Conclusion.

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**TOTAL 43**

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**Reference Books:**

1. Zhaklina Stamboliska, Eugeniusz Rusinski, Przemyslaw Moczko, “*Proactive Condition Monitoring of Low-Speed Machines*”, Springer International Publishing Switzerland 2015.
2. Hydroelectric Research and Technical Services Group, “*Facilities Instructions, Standards, and Techniques (FIST) Volume 3-31, Transformer Diagnostics*”, United States Department of the Interior, Bureau of Reclamation, June 2003.
3. Peter Tavner, Li Ran, Jim Penman, Howard Sedding, “*Condition Monitoring of Rotating Electrical Machines*”, The Institution of Engineering and Technology, London, United Kingdom, 2008.
4. Hamid A. Toliyat, Subhasis Nandi, Seungdeog Choi, Homayoun Meshgin-kelk “*Electric Machines Modeling, Condition Monitoring and Fault Diagnosis*”, CRC Press, Taylor & Francis Group.
5. Kulkarni S. V. and Khaparde S. A., “*Transformer Engineering – Design, Technology and Diagnostics*” 2<sup>nd</sup> Edition, CRC Press, New York.

**Course Outcomes (COs):**

At the end of this course students will demonstrate the ability to:

1. Identify and understand the significance of role of condition monitoring.
2. Assess the condition of various electrical equipments.
3. Identify amount of damage/deterioration in the electrical equipments.
4. Check the mechanical integrity of the electrical equipments.
5. Implement condition monitoring plan for complete electrical system