



GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Master of Engineering

Level: PG

Subject Code: ME02000801

Subject Name: Condition Monitoring and Prognosis of Electrical Equipment

w. e. f. Academic Year:	2024-25
Semester:	2
Category of the Course:	Professional Elective Course

Prerequisite:	Fundamentals of Electrical Machines, Electrical Measurements
Rationale:	Power Systems and Industrial Plants consist of number of electrical drives, transformers, circuit breakers and other equipment which require regular monitoring and health assessment. Numerous techniques are available for the task. This course will enable the students to understand the concepts, principles and acquire basic skills of condition monitoring and diagnostics of electrical equipment in power stations, substations and industry.

After learning the course the students will be able to

Sr. No.	Course Outcome	Weightage
1	Evaluate the condition of electrical installations using advanced insulation assessment techniques.	20
2	Develop a comprehensive condition monitoring plan tailored to specific electrical systems.	15
3	Analyze diagnostic data to identify the extent of damage and degradation in electrical equipment.	25
4	Examine the mechanical integrity and operational reliability of transformers, rotating machines, and circuit breakers.	30
5	Apply modern diagnostic tools and techniques, including AI, IoT, and advanced sensor technology, for predictive maintenance and health monitoring.	10

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P		Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	5	70	30	30	20	150



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Content:

Sr. No.	Topics	Total Hrs.	% Weightage
1.	<p>Advanced Maintenance and Condition Monitoring: Importance and necessity of maintenance, different maintenance strategies like Breakdown maintenance, planned maintenance and condition-based maintenance. Planned and preventive maintenance of transformer, induction motor and alternators. Insulation stressing factors, insulation deterioration, polarization index, dielectric absorption ratio. Insulation ageing mechanisms, Insulation failure modes, Definition of terms, Overview of Advanced tools and techniques (AI & IOT) of condition monitoring, Variety of sensors for Current, Voltage etc parametric monitoring for direct signature analysis for given network condition & equipment health.</p>	4	10
2.	<p>Transformer Diagnostics Technique (Part-1) Introduction, Transformer failure pattern and failure analysis, Aging of electrical Power infrastructure, Diagnostic method, Transformer oil paper insulation system, Remaining life analysis (Statistical Techniques), Robotic unit for direct immersion in transformer tanks for high resolution imaging and integrated condition assessment without draining transformer oil</p>	4	10
	<p>Conventional tests, Dissolved Gas Analysis, Gas Evolution in a Transformer, Key Gas method, IEEE Method, Gas Ratio Method, Fault Detectability using DGA, Combine Criteria for DGA</p>	4	10
	<p>Degree of Polymerization and Furan Analysis, Moisture analysis in Transformer Oil, Time domain Dielectric Response Methods, Polarization and depolarization current measurements, Frequency Domain Dielectric Frequency Response (DFR) Method, Introduction and Basic Philosophy, Advantages and Disadvantages of DFR measurement in Time and Frequency domain</p>	4	10
3.	<p>Transformer Diagnostics Technique (Part-2) Partial Discharge measurements, PD Measuring circuits, calibration, signature analysis, Indirect electrical measurement, UHF sensor and HF CT, Measurement of PD under DC, Acoustic Technique, Evolution, Principle, Overview of Acoustic Technique.</p>	4	20
	<p>Detection of Winding Displacements, Sweep Frequency Response Analysis, Basic features of SFRA response, connection methods, Transfer function features, FRA Test Types, Basics of FRA interpretation, Influence of winding parameters on FRA, Online FRA measurement</p>	4	
	<p>OLTC and Bushing diagnostics, Accessories, Life Assessment and Refurbishment</p>	2	



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4.	<p>Condition Monitoring of Rotating Electrical Machines Introduction to motor condition monitoring, The need for monitoring, What and when to monitor, Construction, operation and failure modes of electrical machines, Structure of electrical machines and their types, Machine specification and failure modes, Failure sequence and effect on monitoring, Typical root causes and failure modes, General, Root causes, Failure modes.</p>	4	10
5	<p>Temperature monitoring Instrumentation requirement for Temperature measurement, Local temperature measurement, Hot-spot measurement and thermal images, Bulk measurement</p> <p>Chemical monitoring Insulation degradation, Factors that affect detection, Insulation degradation detection, Particulate detection: core monitors, Particulate detection: chemical analysis, Gas analysis off-line, Gas analysis on-line, Lubrication oil and bearing degradation.</p> <p>Motor Current Signature Analysis Identifying methods of Mechanical Faults with Motor Current Signature Analysis (MCSA), faults that can be Detected with MCSA: Air-Gap Eccentricity, Broken Rotor Bars, Bearings Damage, Shorted Turns in Stator Windings, etc.</p> <p>Vibration monitoring Instrument required for Vibration measurement, Condition monitoring of rotating elements, Bearing response, Rolling element bearings, bearing geography, Bearing Monitoring techniques, Overall level monitoring, Frequency spectrum monitoring. Sensors for foundation tilt, drive shaft twisting etc. monitoring</p>	6	15
6.	<p>Condition monitoring and diagnostics of electrical circuit breakers Contact Resistance Measurement, Timing Analysis, Dynamic Resistance Measurement (DRM), Partial Discharge (PD) Testing, Gas Analysis for SF₆ Circuit Breakers, Vibration Analysis, Thermal Imaging, Insulation Resistance Testing, Circuit Breaker Analyzer, Acoustic Emission Testing, Trip Coil Current Analysis, Mechanical Travel Analysis, travel curve including position, angular & linear sensors for kinematic chain health/ twist monitoring, self-powered wireless sensors for contact temperature monitoring, micro motion pulses for overall electrical circuit health without creating breaker operation</p>	6	15



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Reference Books:

1. Kulkarni S. V. and Khaparde S. A., “Transformer Engineering – Design, Technology and Diagnostics” Second Edition, CRC Press, New York
2. T. S. Ramu and H N Nagamani, “Partial Discharge Based Condition Monitoring of High Voltage Equipment” New Age International, New Delhi
3. W. H. Tang and Q. H. Wu, “Condition Monitoring and Assessment of Power Transformers Using computation Intelligence”, Springer, London 2010
4. Peter Tavner, Li Ran, Jim Penman and Howard Sedding, “Condition Monitoring of Rotating Electrical Machines”, Published by The Institution of Engineering and Technology, London, United Kingdom, 2008
5. Hamid A Toliyat, Subhasis Nandi, Seungdeog Choi, Homayoun Meshgin-Kelk, “Electric Machines: Modeling, Condition Monitoring and Fault Diagnostics, CRC Press
6. Chakravorti Sivaji, Dey Debangshu, Chatterjee Biswendu, “Recent Trends in the Condition Monitoring of Transformers- Theory, Implementation and Analysis” Springer, 2013
7. Greg C. Stone, Edward A. Boulter, Ian Culbert, Hussein Dhirani, “Electrical Insulation for Rotating Machines: Design, Evaluation, Aging, Testing, and Repair”, IEEE Press Series on Power Engineering, A John Wiley & Sons, Inc., Publication, 2004
8. R.E. James and Q. Su, “Condition Assessment of High Voltage Insulation in Power System Equipment”, Published by The Institution of Engineering and Technology, London, United Kingdom, 2008
9. Elias G. Strangas et al. “Fault Diagnosis, Prognosis, and Reliability for Electrical Machines and Drives”, John Wiley & Sons, New Jersey, 2022

Course Outcome:

List of Experiments:

1. To perform/study various techniques of Dissolve gas Analysis such as IEEE method, key gas method, ratio method and Duval triangle method
2. To perform/study/detect Partial discharge in Electrical Equipment based on Electrical PD detection technique
3. To perform/study frequency response analysis on Transformer winding based on various connections
4. To perform/study of thermo graphic diagnosis system based condition monitoring practices.
5. To perform/study overall vibration analysis of rotating machine.
6. To perform Spectrum/FFT Analysis of rotating machine vibration.
7. To perform Current Signature Analysis of rotating machine.
8. Identifying methods of Mechanical Faults with Motor Current Signature Analysis



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Open Ended Problems/Suggested Student Activities:

- Arrange a visit to nearby industry/substation, ERDA to observe Condition monitoring and Diagnostics of various electrical equipment and machines.
- Arrange expert lectures of the professional engineers involved in Condition Monitoring and Diagnostics of heavy power equipments/machines.
- Use Flash/Animations to demonstrate Diagnostics of various electrical equipment and devices.

Major Equipment:

1. Dissolve Gas Analyzer.
2. Partial Discharge Detection Kit/ Faraday Cage
3. Frequency Response Analyzer
4. Dielectric Frequency Response Analyzer
5. Furan Analyzer
6. Infrared Temperature Meter
7. Digital Vibration Meter
8. AC/DC Current Sensor/Prob.
9. Data Acquisition System with Analog Inputs and Signal Conditioner
10. Digital Spectrum Analyzer

List of learning website/Standards/Resources:

1. <http://www.bis.org.in/index.asp>
2. CIGRE working group report: WA2.34, Guide for Transformer maintenance.
3. http://www.ieee.org/publications_standards/publications_standards_index.html
4. <http://www.nema.org/Standards/About-Standards/pages/default.aspx>
5. CIGRE working group report: A2.26 Mechanical-Condition Assessment of Transformer windings using Frequency Response Analysis (FRA)
6. <http://www.ni.com/condition-monitoring/>
7. <http://spectraquest.com/resources/technotes/>
8. Rogers RR (1978) IEEE and IEC codes to interpret incipient faults in transformers using gas in oil analysis, IEEE Trans Electrical Insulation 13(5): 348-354.
