Master of Technology

In

Electrical Engineering
(Condition Monitoring of Power Apparatus)

Course Structure & Syllabus

Department of Electrical Engineering

National Institute of Technology Hamirpur

Hamirpur (HP) – 177005, India

Course Structure of M. Tech. Electrical Engineering (Condition Monitoring of Power Apparatus)

SEMESTER- I

Sr. No.	Course No.	Course Name	Teaching Schedule			Hours/week	Credit
			L	T	P		
1	EE-651	Transformer Engineering & Practices	4	0	0	4	4
2	EE-652	HV Diagnostic Techniques	4	0	0	4	4
3	EE-653	Sensors and Signal Conditioning	4	0	0	4	4
4	EE-7MN	Programme Elective-I	4	0	0	4	4
5	EE-7MN	Programme Elective-II	4	0	0	4	4
6	EE-654	Electrical Apparatus Diagnostic Lab-I	0	0	4	4	2
	Total		**20**	**0**	**4**	**24**	**22**

Programme Elective-I & II: List of Programme Electives is given in the Annexure.

SEMESTER- II

Sr. No.	Course No.	Course Name	Teaching Schedule			Hours/week	Credit
			L	T	P		
1	EE-661	Power Transformer Design	4	0	0	4	4
2	EE-662	Condition Monitoring of Power Apparatus	4	0	0	4	4
3	EE-663	Advanced Power System Protection	4	0	0	4	4
4	EE-7MN	Programme Elective-III	4	0	0	4	4
5	EE-7MN	Programme Elective-IV	4	0	0	4	4
6	EE-664	Electrical Apparatus Diagnostic Lab-II	0	0	4	4	2
	Total		**20**	**0**	**4**	**24**	**22**

Programme Elective -III & IV: List of Programme Electives is given in the Annexure.

SEMESTER- III

Sr. No.	Course No.	Course Name	Hours/week	Credit
1	EE-800	M.Tech. Dissertation	--	20
	Total		**--**	**20**

SEMESTER- IV

Sr. No.	Course No.	Course Name	Hours/week	Credit
1	EE-800	M.Tech. Dissertation	--	20
	Total		**--**	**20**

Annexure

List of Programme Electives

Programme Elective-I

EE-711 AI Techniques and Applications
EE-712 Optimization Techniques
EE-713 Genetic Algorithm and Evolutionary Programming

Programme Elective-II

EE-751 Risk and Reliability Engineering
EE-752 Testing and Maintenance of Electrical Power Apparatus
EE-753 Energy Auditing & Management

Programme Elective-III

EE-723 Power Signal Processing
EE-761 Solid State Devices and Converters
EE-762 High Voltage Engineering

Programme Elective-IV

EE-724 Solid State Control of Drives
EE-726 Distributed Generation and Microgrid
EE-728 Signal Conditioning and Data Acquisition
EE-745 Microprocessor Based Instrumentation System

Course Name: **Transformer Engineering and Practices**
Course Code: **EE-651**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the transformer engineering & practices.
- To introduce the fundamental concepts relevant to transformer magnetic circuits, winding, insulation, cooling, etc.
- To enable the students to understand the factors related with practices related with transformer.

Course Content

Materials for transformers: Insulating oil, insulating paper, pressboard, wood, insulated copper conductor for windings, crepe paper, sealing materials, cold–rolled grain oriented electrical steel sheet, structural steel, future trends. Magnetic Circuit: Materials, design of magnetic circuit, optimum design of core. Winding and Insulation: Types of windings, surge voltage, heat transfer, insulation design. Tap Changers: Off-circuit tap changer, on load tap changer, automatic control of tap changer. Forces in Power Transformers: Leakages flux. Axial and radial forces, methods of force calculation, reinforcement of coils to withstand short circuit forces. Cooling Arrangements: Types of cooling and cooling arrangements, propeller fans and oil pumps, flow indicators. Transformer Auxiliaries: Buchholz relay, temperature indicators, oil level indicators, oil preservation systems, silica gel breather, gas sealed conservators.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify various concepts of transformer engineering & practices.

CO2: Describe important concepts related with to transformer magnetic circuits, winding, insulation, cooling and various forces.

CO3: Apply principal to explain various problems related with concepts described in CO2.

CO4: Assess the results obtained by solving above problems.

Books and References

1. Transformers by BHEL, Bhopal, Tata McGraw Hill.
2. Transformer Engineering by S. V. Kulkarni and S. A. Khaparde Marcel & Dekks Inc.
3. Transformer Engineering Design and Practices by S. V. Kulkarni, S. A. Khaparde, Marcel Dekker Inc., New York.

Course Name: **HV Diagnostic Techniques**
Course Code: **EE-652**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To provide students with an introduction to high voltage engineering, phenomena and technology.
- To understand high voltage generation, measurement and testing.
- To understand diagnostics methods for protection of high voltage apparatus.

Course Content

Insulation Materials and Systems: Insulation system in practice, dielectric losses, ageing and life expectancy: Outdoor insulation: Materials, ageing, diagnostic, polymeric materials, semi-conducting ceramic glazes, AC and impulse voltage flashover studies on a string of insulators, RIV and Corona Studies on insulator strings, High voltage testing. Dry, wet and pollution testing, high current testing, composite stress testing. Insulation Failure: Dielectric Formalism, equivalent circuits, intrinsic dielectrics strength, mechanisms of electrical and thermal breakdown in solids, dielectric relaxation in condensed matter, phenomenological theory of ageing, mechanisms of ageing under electrical, thermal and combined stresses, accelerated ageing tests, statistical models for insulation failure, ageing data analysis, ageing and failure due to partial discharges, ageing in multi-component insulation system. Diagnostics and Condition Monitoring: Need for diagnostics and condition monitoring, on-line/on-site testing, diagnostic tests, transformer impulse test, neutral current method, digital techniques, data acquisition principles and problems, TF and CF method, winding structure, natural frequencies, newer methods for fault identification and diagnostics, PD measurement, background, analysis, calibration, digital PD measurement, PD as a diagnostic tool, PD signal, noise reduction methods, PD pattern, residual life Assessment, SFRA test on transformer, Breakdown Voltage test and Dissolved Gas Analysis.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Describe how insulation diagnostic techniques are helpful in HV.
CO2: Explain and analyze the impact of these HV techniques.
CO3: Derive basic mathematical analysis for their application in diagnosis.
CO4: Perform calculations on insulation failure.
CO5: Model and analyze health assessment of HV equipment.

Books and References

1. High Voltage Engineering by M. S. Naidu, V. Kamaraju, McGraw Hill.
2. High Voltage Engineering & Testing by H. M. Ryan, Petr Pregrinus.
3. Dielectric Breakdown of Solids by Whitehead S, Oxford University Press, Clarendon.
4. High Voltage Engineering: Theory & Practice by M. Khalifa, Dekker.

Course Name: Sensors and Signal Conditioning
Course Code: EE-653
Course Type: Core

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the select ion of the appropriate transducers/sensors for various applications of measurement of non-electrical quantity in industrial process, electrical power system, electrical machines, utilization system.
- To introduce the fundamental concepts relevant to identify signal conditioning circuit for Instrumentation system for condition monitoring in industrial process, electrical power system, electrical machine operation, measurement and control.
- To enable the students to understand and identify appropriate transducers/sensors with suitable signal conditioning circuit for given application.

Course Content

Introduction to Sensors and transducers; Primary sensors: temperature sensors, pressure sensors, flow sensors, level sensors, acceleration sensors, torque measurement, synchro; Resistive sensors: strain gauge, thermistors, magneto-resistors, light dependent resistors; Self-generating sensors: thermoelectric, piezoelectric, pyrometer, photovoltaic sensors; capacitive sensors; inductive sensors ; dissolved oxygen sensor ; digital sensor encoder; gas chromatography; photo-acoustic spectroscopy; ultrasonic sensors; ultra-high frequency sensors; optical-fibre sensors; smart sensors. Signal conditioning**:** Analog signal conditioning: Principles of analog signal conditioning, signal-level changing, linearization, conversions, zero adjustment, span adjustment, filtering and impedance matching, passive circuits, divider circuit, bridge circuits, operational amplifiers, characteristics, Op Amp circuits in instrumentation, voltage follower, differential amplifier, instrumentation amplifier, active filters, voltage-to-current converter, current-to-voltage converter. Digital Signal Conditioning: Review of digital fundamentals, busses and tri-state buffers, comparators, digital-to-analog converters (DAC), analog-to-digital converters (ADCs), sample and hold, multiplexer and de-multiplexer, decoder and encoder, digital recorder, programmable logic controller, Interfacing sensors with microprocessors/micro- controllers.

Course Outcomes

Upon successful completion of the course, the students will be able to have

CO1: Understanding of sensors and transducers and to know about the basic instrumentation systems and signal conditioning circuits

CO2: An idea about the evolution of microprocessors/microcontrollers and explain the fundamental features and operation of contemporary microprocessors and microcontrollers

CO3: Understanding of various types of signal conditioning circuits

CO4: Understanding of the interfacing of ADC, DAC, S/H, and sensors/transducers to microprocessor/ microcontroller using peripheral devices

Books and References

1. Transducers in instrumentation by D. V. S. Murthy, Prentice Hall.
2. Principles of measurement systems by J. P.Bentley , Wiley.
3. Condition Assessment of High Voltage Insulation in Power System Equipment by R.E. Jamesw and Q. Su, IET Power and Energy Series 53.
4. Semiconductor Sensors by S. M. Sze, Wiley.
5. Measurement Systems by E.O. Doebelin, Mc Graw Hill.
6. Analog Signal Processing by John G Webster, Wiley Eastern Publication.
7. Sensors and Signal Conditioning by Ramon Pallas-Areny, Wiley.

Course Name: **AI Techniques and Applications**
Course Code: **EE-711**
Course Type: **Programme Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the application of artificial intelligence techniques in electrical engineering.
- To introduce the fundamental concepts relevant to fuzzy logic, artificial neural network, genetic algorithm, Evolutionary techniques and Hybrid systems.
- This activity aims to get students thinking critically about what specialty makes humans intelligent, and how computer scientists are designing computers to act smartly or human like.

Course Content

Artificial Intelligence: Definition, problem solving methods, searching techniques, knowledge representation, reasoning methods, predicate logic, predicate calculus, multi-value logic. Fuzzy Logic: Concepts, fuzzy relations, membership functions, matrix representation, de-fuzzification methods. Artificial Neural Network: Introduction, multi-layer feed forward networks, back propagation algorithms, radial basis function and recurrent networks. Evolutionary Techniques: Introduction and concepts of genetic algorithms and evolutionary programming. Hybrid Systems: Introduction and Algorithms for Neuro-Fuzzy, Neuro-Genetic, Genetic-Fuzzy systems.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify different searching techniques, constraint satisfaction problem and example

CO2: Able to apply these techniques in different field, which involve perception, reasoning and learning.

CO3: Analyze and design a real world problem for implementation and understand the dynamic behavior of a system.

CO4 : Assess the results obtained by ANN, Genetic algorithm and fuzzy systems.

Books and References

1. Artificial Intelligence and Intelligent Systems by N. P. Padhy , Oxford University Press.
2. Neural Networks, Fuzzy Logic and Genetic Algorithm Synthesis and Applications by Rajasekaran S. and Pai G.A.V., PHI New Delhi.
3. Neural Fuzzy Systems by Lin C. and Lee G., Prentice Hall International Inc.
4. Genetic Algorithms in Search Optimization & Machine Learning by Goldberg D.E., Addition Wesley Co., New York.
5. Neural Networks & Fuzzy Systems A dynamical systems approach to machine intelligence by Kosko B., Prentice Hall of India.

Course Name: Optimization Techniques
Course Code: EE-712
Course Type: Programme Elective-I

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the principles of optimization techniques.
- To introduce the fundamental concepts relevant to classical optimization methods, linear programming, nonlinear programming and dynamic programming.
- To enable the students to understand the factors that cause the different optimization methods to provide different solutions for the same mathematical problem.

Course Content

Introduction to optimization; Objective function; Constraints and Constraint surface; Classification of optimization problems; Optimization techniques – classical and advanced techniques, linear programming (LP) problem; Elementary operations; Graphical method for two variable optimization problem; Examples; Motivation of simplex method, Simplex algorithm and construction of simplex tableau; Simplex criterion; Minimization versus maximization problems; simplex method with artificial variables; Optimization using Calculus**,** Stationary points - maxima, minima and saddle points; Global Optimum; Convexity and concavity of functions of one and two variables; Optimization of function of one variable and multiple variables; Gradient vectors; Examples; Optimization of function of multiple variables subject to equality constraints; Lagrangian function; Optimization of function of multiple variables subject to inequality constraints; Hessian matrix formulation; Eigen values; Kuhn-Tucker Conditions; Examples, nonlinear programming, one dimensional minimization methods, unconstrained optimization methods, direct search methods, descent methods, 2^{nd} order methods, constrained optimization, indirect methods, exterior penalty function, interior penalty function, geometric view point, augmented lagrange multiplier, kuhn tucker conditions, introduction to dynamic programming, sequential optimization; representation of multistage decision process; types of multistage decision problems; concept of sub optimization and the principle of optimality; Recursive equations – Forward and backward recursions; Computational procedure in dynamic programming (DP); Discrete versus continuous dynamic programming; curse of dimensionality in DP, example.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify different types of optimization techniques and problems.

CO2:Describe techniques like calculus based classical optimization, linear programming, nonlinear programming, dynamic programming.

CO3: Apply principles and techniques described in CO2 to solve sample mathematical and practical optimization problems.

CO4: Assess the results obtained by applying optimization techniques to solve mathematical programming problems.

Books and References

1. Engineering Optimization: Theory and Practice by S.S. Rao, New Age International (P) Ltd., New Delhi.
2. Numerical Optimization with Applications by Suresh Chandera, Jaydeva, and Aparna Mehta, Narosa.
3. An Introduction to Optimization by Edvin K.P. Chong, and Stanislaw H. Zak Publisher: John Wiley.
4. Optimization Theory and Practice by Mohan C. Joshi and Kannan M Moudgalya, Narosa.

Course Name: Genetic Algorithms and Evolutionary Programming
Course Code: EE-713
Course Type: Programme Elective-I

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about related with Genetic algorithm and Evolutionary programming.
- To introduce the fundamental concepts relevant to GA operators, creation of offspring etc.
- To enable the students to understand the factors related with application and fundamental of GA and EP.

Course Content

Introduction, Basic concepts and definitions, artificial intelligence, genetic algorithms (GAs), evolutionary programming (EP), Genetic algorithm, Coding, fitness function, Calculation of the number of bit required for a variable, GAs operators, crossover and mutation, roulette wheel method for selection process, cumulative probabilities, Basic flow chart, GAs for optimization detail steps, Similarities between GAs and traditional methods, Differences between GAs and traditional methods, Evolutionary programming, Initialization, Creation of offspring, Competition and selection, Gaussian random numbers, standard deviation, Difference between GAs and EP, basic algorithm, step by step procedure of evolutionary programming for optimization. Applications of GAs for economic power dispatch and optimal power flow, applications of EP for economic power dispatches and optimal powers flow.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify various concepts of Genetic algorithm and Evolutionary programming.

CO2: Describe important concepts related with optimization with GA and EP.

CO3: Apply principal to explain various problems related with problems described in CO2.

CO4: Assess the results obtained by solving above problems.

Books and References

1. Genetic Algorithms, Data Structures and Evolution Programs by Z. Michalewicz, Berlin: Springer-Verlag.
2. Genetic Algorithms in Search, Optimization and Machine Learning by D.E. Goldberg, Addison-Wesley.
3. Genetic Algorithms for VLSI Design, Layout & Test Automation by Pinaki Mazumder and Elizabeth M. Rudnick, Prentice Hall PTR.

Course Name: **Risk and Reliability Engineering**
Course Code: **EE-751**
Course Type: **Program Elective-II**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the concept of reliability of physical high voltage equipments.
- To introduce fundamental concepts relevant to reliable design, reliable operation and safety of electrical equipments.
- To enable the students, understand impact of various factors including cost, quality of materials on dimensions of HV systems.
- To impart knowledge concerning residual life assessment of power equipments.

Course Content

Introduction to reliability concepts, unit and system reliability aspects for various category of High Voltage Electrical Systems and relevance with regard to asset maintenance, Various factors including safety requirements as per national and international standards, compatibility of insulation materials in various electrical equipment's from user and condition assess- ment point of view. Reliability Models, System reliability, Forward models, Density and distribution functions, fault tree analysis, HAZOP Analysis, Risk and criticality Analysis, Maintainability Analysis, Relevance of each analysis from asset management point of view ,Reliability Centric Calculations ,Calculations of maintainability parameters, Availability Calculations and maintenance management ,Impact on Product Quality, Introduction to product quality specifications, factors influencing product cost, size, limits with regard to portability, transportation and similar aspects, Statistical quality control, Introduction of ISO 900 series, Total Quality Management and related issues. Applications of Risk and Reliability Tools, Application of Risk analysis tools to at least three different category of electrical power system network problems-based Case Studies concerning use of reliability engineering in real life electrical equipment risk analysis from estimating life of equipment's in substations of an electrical utility.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand and apply various reliability centric tools to ensure trouble free operation of electrical systems.
CO2: Describe contribution of various factors influencing risk assessment analysis which if ignored can lead to failure of electrical assets.
CO3 : Apply proper design principles in order to ensure reliable functionality and safer use of key substation and other equipment's considering key threats.
CO4 : Carry out statistical quality control analysis for reliable performance of electrical assets as per ISO and TQM guidelines.

Books and References

1. IET Power and Energy Series 53 by RE James on Condition Assessment of High Voltage Insulation Published By IET London.
2. High Voltage Engineering by E. Kuffel and Zaengal, Butterworth-Heinemann.
3. Statistical Techniques for HV engineering, IET Power Series no 13, IET London.
4. Reliability and Life Estimation of Power Equipment by Ramu T.S., New Age International Publishers.

Course Name: Testing and Maintenance of Electrical Power Apparatus
Course Code: EE-752
Course Type: Programme Elective-II

Contact Hours/Week: 4L | **Course Credits: 04**

Course Objectives

- To know practical issues concerning need of carrying out maintenance practices in various utility substations.
- To learn various tools, type tests and routine tests to ascertain various possible faults in power apparatus.
- To know about characterization of electrical dielectrics and impact on reliable operation of equipment.
- To enable students, learn procedure to carry out field tests, sampling procedure etc. to carry out lab as well as field tests.
- To learn procedures for safe operation, safety measures to be adopted in event of electrical accidents.

Course Contents

Introduction to Electrical Equipment maintenance and testing: Overview of Electrical preventive maintenance and testing, overview of testing and test methods, review of dielectric theory and practice. DC Voltage testing of Electrical Equipment: DC voltage testing of insulation, DC testing methods; transformers, Cables, circuit breaker motor & generators and capacitors. Precautions when making DC tests. AC Voltage testing methods: Power factor and dissipation factor test methods, basic test connection for PI testing, evaluation and grading of PF and DF test results. Insulating Oil, Fluids and Gases: Insulating liquid sampling procedures, maintenance and reconditioning of insulating oil & fluids, insulating gases. Transformer: Transformer categories and types, application and use, transformer polarity, terminal markings and connection, transformer characteristics, preventive maintenance of transformers, transformer testing. Electrical Power Apparatus Grounding & Ground resistance measurements: Selection of grounding method, selection of grounding system, ground resistance values, ground resistance measurements. Electrical Safety Switching Practices and precautions.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Able to Identify various kind of tests related with power equipment's located in electric power sub stations networks.

CO2: Able to describe role of diagnostic tests before a catastrophic failure of power apparatus

CO3: Apply principles and tools to carry out AC and DC tests to highlight dielectric strength of insulation used in power transformers.

CO4: Able to develop skill for using safe practices and prevent accidents, human loss, asset damage in event of fires etc. if at all it occurs in field despite precautions.

Books and References:

1. Electrical Power Equipment Maintenance and Testing by Paul Gill, Marcel Dekker Inc, New York.
2. Operating, Testing and Preventive Maintenance of Electrical Power Apparatus by Charles I, Hubert, Prentice Hall.

Course Name: Energy Auditing and Management
Course Code: EE-753
Course Type: Programme Elective-II

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge in the domain of energy conservation and management.
- This activity aims to get students thinking critically about assessing the energy efficiency of an entity/ establishment.
- To bring out Energy Conservation Potential and Business opportunities across different user segments.

Course Content

Understanding, analysis and application of electrical energy management-measurement and accounting techniques-consumption patterns- conservation methods-application in industrial cases. System approach and End use approach to efficient use of Electricity; Electricity tariff types; Energy auditing: Types and objectives-audit instruments-ECO assessment and Economic methods-specific energy analysis-Minimum energy paths-consumption models-Case study. Electric motors-Energy efficient controls and starting efficiency- Motor Efficiency and Load Analysis- Energy efficient /highly efficient Motors-Case study; Load Matching and selection of motors. Variable speed drives; Pumps and Fans-Efficient Control strategies- Optimal selection and sizing - Optimal operation and Storage; Case study Transformer Loading/Efficiency analysis, Feeder/cable loss evaluation, case study. Reactive Power management- Capacitor Sizing-Degree of Compensation-Capacitor Losses-Location-Placement-Maintenance, case study. Peak Demand controls- Methodologies-Types of Industrial Loads-Optimal Load scheduling-case study. Lighting- Energy efficient light sources-Energy conservation in Lighting Schemes- Electronic Ballast-Power quality issues-Luminaries, case study. Cogeneration- Types and Schemes-Optimal operation of cogeneration plants-case study; Electric loads of Air conditioning & Refrigeration-Energy conservation measures- Cool storage. Types-Optimal operation-case study; Electric water heating-Geysers-Solar Water Heaters- Power Consumption in Compressors, Energy conservation measures; Electrolytic Process; Computer Controls- software-EMS.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Obtain the knowledge about energy conservation act, policy, regulations and business practices.

CO2: Analyse different energy systems from a supply and demand perspective.

CO3: Recognize opportunities for rational use of energy in industrial application.

CO4: Apply knowledge of Energy Conservation Opportunities in a range of contexts.

CO5: Identify and Develop innovative energy efficiency solutions and demand management strategies for future.

Books and References

1. Handbook on Energy Audit and Environment Management by Y P Abbi and Shashank Jain, TERI.
2. Handbook of Energy by Audits Albert Thumann, William J. Younger, Terry Niehus.
3. Industrial Energy Management: Principles and Applications by Giovanni Petrecca, The Kluwer international series.
4. Guide to Electric Load Management by Anthony J. Pansini, Kenneth D. Smalling, Pennwell Pub.
5. Energy-Efficient Electric Motors and Their Applications by Howard E. Jordan, Plenum Pub Corp.
6. Energy Management Handbook by Turner, Wayne C., Lilburn, The Fairmont Press.
7. Handbook of Energy Audits by Albert Thumann. Fairmont Pr.
8. Recommended Practice for Energy Conservation and cost-effective planning in Industrial facilities, IEEE Bronze Book, IEEE Inc, USA.
9. Plant Engineers and Managers Guide to Energy Conservation by Albert Thumann, P. W, TWI Press Inc, Terre Haute.

Course Name: Electrical Apparatus Diagnostic Lab-I
Course Code: EE-654

Contact Hours/Week: **4P** | Course Credits: **02**

Course Objectives

- To provide skills for carry out handling of various HV equipment's and tasks related with safe operation, making proper connections, take measurements in HV lab equipment's.
- To provide skills for assessing healthiness of electrical insulations.
- To enable the students, learn handle safety norms and exercise precautions while working in a HV Lab.

List of Experiments

1. To find the dielectric breakdown Voltage of a given sample of Solid Insulation paper or insulation sheet in HV Lab.
2. To find the dielectric breakdown voltage of a given sample of transformer oil under different electrode spacings.
3. To study pour point of a given sample of Transformer Oil
4. To find the Dielectric Constant and Resistivity of a given sample of Transformer Oil by using C & Tan Delta test set
5. To investigate dissolved decay contents in a given sample of Transformer Oil by using UV-VIS Spectrophotometer test set.
6. To determine the Interfacial Tension of given sample of Transformer Oil
7. To determine dissolved gaseous contents to ascertain incipient faults in an oil filled power transformer by using DGA test set
8. To carry out air insulation breakdown studies by using uniform and non-uniform electrodes in HV Lab.

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.*

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify and interpret health condition of the solid insulations as well as liquid dielectrics used in power transformer / electrical machines located in a substation.

CO2: Design and develop aging based scheme for ensuring trouble free operation of power equipment's.

CO3: Develop safety norms to ensure safety of personals doing HV tests in a HV lab.

Course Name: Power Transformer Design
Course Code: EE-661
Course Type: Core

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To learn about various specifications and design concepts of power transformer.
- To have knowledge about material used in core, windings, insulation and cooling.
- To impart knowledge about computer aided design for power transformer.

Course Content

End Users Specifications: Requirement of specification, mandatory specification, supplementary specification, additional specification, standard GTP format. Basic Concept of Design: Review of basic materials and their processing, selection of number of turns, selection of core diameter, selection of winding wires and strips, size HV and LV conductors, transposition, process flowchart. Applications: Design of a 100 KVA transformer, Design of 630 KVA transformer, design of 5 MVA, 33/11 KV transformer. Computer aided design: Basic concept, specification needs, computer programming, variable inputs, program convergence, design output, design modification, other aspects of design, design validation, design package, computer design printout, software application for design.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Analyze the transformer specifications.

CO2: Explain and analyze the design of different parts of transformer.

CO3: To design the entire transformer based on the specifications.

CO4: Explain and analyse various tools required for transformer design.

CO5: To carry out transformer design by using CAD based advanced software.

Books and References

1. Transformer Engineering by S.V. Kulkarni and S.A. Khaparde, Marcel and Dekker Inc.
2. Principles of Electrical Machine Design with Computer Programs by S. K. Sen, Oxford & IBH Publishing Co. Pvt. Ltd.
3. Design of Transformers by Inderjit Das Gupta, Tata McGraw Hill.

Course Name: Condition Monitoring of Power Apparatus
Course Code: EE-662
Course Type: Core

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To know practical issues concerning need of carrying out condition monitoring practices in various utility substations.
- To learn various tools of condition assessment for proper diagnosis of faults in power apparatus.
- To derive basic mathematical expressions for analysis & characterization of electrical equipment insulation.
- To enable students, learn procedure to carry out health assessment studies for costly power apparatuses in field.

Course Contents

Introduction: Condition monitoring & diagnostics engineering management, Techniques employed in the field of condition monitoring, Identification of equipment's in sub-station. Characterization of electrical equipment insulation condition: Permittivity & capacitance, resistance & insulation resistance, time constants, dielectric dissipation factor, partial discharge, physical & chemical changes, modes of deterioration & failure of practical insulating materials, dielectric losses, partial discharge – sources, forms and effects, ageing effects, damage due to partial discharge, thermal stress, ageing overview of identification of major requirements for electrical insulating materials, concept of insulation design. Power Transformer Condition Monitoring : Transformer oil testing and Interpretation – Introduction, mineral insulating oil, four functions of transformer oil , causes of oil ageing, ageing rate accelerators, control of acceleration factors, development of a comprehensive testing program, various tests on transformer oil such as power factor, moisture, neutralization number, interfacial tension, relative density, color, visual examination, BDV, dissolved gas analysis, furanic compounds, Electrical testing of transformer - Various electrical tests on transformer such as power factor, turns ratio, DC resistance test, Insulation resistance test, Leakage reactance, frequency response analysis, partial discharge and their interpretation as per national standards and guidelines, concept of condition index evaluation of transformer, transformer bushing diagnostics, degree of polymerization and remaining life; their interpretation as per national and international standards. Condition Monitoring of Rotating Electrical Machines: Introduction, electric motor failures, simple preventive techniques, methods of motor monitoring such as current , temperature, starting strategies and soft starts, resistance, lubrication, cleaning, general inspection, advanced techniques for electric generator monitoring, vibration monitoring, stator current monitoring.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Able to Identify various modes of failures of power equipment's located in electric power sub stations networks.

CO2: Able to describe various diagnostic tests related with condition assessment of power apparatus.

CO3: Apply principles and tools to carry out condition assessment studies related with power transformers.

CO4: Able to develop skill to assess and interpret the diagnostic test results for health assessment concerning residual life enhancement and reliable operation before any catastrophic failure of power equipment occur.

Books and References

1. Handbook of Condition Monitoring by B. K. N. Rao, Elsevier Science Publisher.
2. Condition Assessment of High Voltage Insulation in Power System Equipment by R.E James, Publisher IET.
3. Condition Monitoring of Rotating Electrical Machine by P. J. Tavner, J. Penman, Publisher IET.

Course Name: Advanced Power System Protection
Course Code: EE-663
Course Type: Core

Contact Hours/Week: **4L** | Course Credits: **04**

Course Objectives

- To understand the general philosophy of protection, selection criteria and parameters of protection.
- To identify the need and type of relays and their applications with design.
- To enable the students to understand the concept of modern coordinated control and protection of power system.

Course Content

Introduction: General Philosophy – Characteristic function of protective relay – basic relay elements and relay terminology – basic construction of static relay. Protection of Power Apparatus: Protection of generators stator phase fault protection – loss of excitation protected generator off-line protection – Transformer protection – factors affecting differential protection – magnetizing inrush current – transformers over current protection – motor protection. Protection of Transmission System: Bus protection – typical bus arrangements – transformer – bus combination – bus differential system. Line protection – classification of lines and feeders – Techniques applicable for line protection – distance protection for phase faults – Fault resistance arc relaying– Backup remote local and breaker failure. Protection of Reactors, Boosters & Capacitors: Placement of reactors system – Types of reactor – reactor rating application and protection – boosters in the power system – transformer tap changing – protection boosters – capacitors in an interconnected power system – series – shunt – series shunt connections – protection of capacitors. Digital Protection: Digital signal processing, Digital filtering in protection relay, digital data transmission, Numeric relay hardware, relay algorithm, distance relays, direction comparison relays, differential relays, software considerations, numeric relay testing, concept of modern coordinated control system.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify different power system protection techniques.

CO2: Describe principles like differential protection, distance protection, overcurrent protection and carrier current protection.

CO3: Apply principles and algorithms of digital protection schemes and modern coordinated control and protection of power system.

CO4: Assess the results obtained by applying above techniques of protection.

Books and References

1. Power System Protection by P. M. Anderson, IEEE Press Series
2. Electrical Power System Protection by Arther Wright, Christo Christopoules, Publisher – Springer.
3. Protective Relays Theory & Practice, Vol-II by A. R. Van &C Wanington, Chapman & Hall.
4. Fundamental of Microprocessor & Microcomputer by B. Ram, Dhanpat Rai & Sons
5. Power System Protection – Static relays by T. S. M. Rao, Tata McGraw Hill Publishing Co.

Course Name: Power Signal Processing
Course Code: EE-723
Course Type: Programme Elective-III

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives:

- To introduce the fundamental concepts of digital signal processing for power system signal.
- To impart knowledge about the signal processing applications for power system protection and power quality analysis.
- To enable the students to understand the concepts of signal processing for grid synchronization.

Course Content

DSP basics-sampling, Fourier series and Fourier transform, DFT, Phasor measurement techniques-phasor representation-DFT, Fourier series, amplitude, phase and frequency estimation of of undistorted single frequency sine wave- two and three sample techniques, phasor estimation using PLL structure and Kalman filter, phasor estimation of nominal and off-nominal frequency inputs, recursive and non-recursive updates, phasor estimation with fractional cycle date window, power system frequency estimation from Balanced and unbalanced input, PMUs, synchro phasors, removal of dc offset, Signal processing and power quality, processing of stationary signals-frequency-domain analysis and signal transformation, estimation of harmonics and inter harmonics, Processing of non-stationary signals- Discrete STFT for Analyzing Time-Evolving Signal Components, Discrete Wavelet Transforms for Time–Scale Analysis of Disturbances Grid synchronization techniques for single-phase and three-phase systems based on PLL and Fourier analysis, Hilbert transform, T/4 transport delay, SOGI, MAF.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify suitable signal processing technique for power signal applications.

CO2: Describe the various signal processing technique for amplitude and phase and frequency estimation of grid signal.

CO3: Apply principles and algorithms of signal processing for power quality analysis.

CO4: Assess the suitability of various filtering techniques for three-phase and single-phase grid synchronization.

Books and References

1. Essentials of Digital Signal Processing by B. P. Lathi, Cambridge University Press.
2. Synchronized Phasor Measurements and Their Applications by A.G. Phadke, J.S. Thorp,Springer.
3. Signal Processing of Power Quality Disturbances by M. H. J. Bollen, Irene Y.H. Gu, IEEE Press.
4. Digital Signal Processing in Power Electronics Control Circuits by Krzysztof Sozan´ski, Springer.
5. Digital Power System Protection by S.R. Bide, PHI.
6. Grid Converters for PV and Wind Power Systems by R. Teodorescu et al, John-Wiley Sons.

Course Name: Solid State Devices and Converters
Course Code: EE-761
Course Type: Programme Elective-III

Contact Hours/Week**: 4L** Course Credits**: 04**

Course Objectives

- To know principle, operation and switching characteristics of key solid-state devices using R, RL, RE and RLE loads.
- To learn application of power electronic devices in 1 phase and 3 phase-controlled converters, Choppers & Inverters.
- To derive mathematical expressions for circuit analysis in respect of input and output converter performances.
- To enable students, learn methods of harmonics mitigation to improve overall performance of power electronic converters.

Course Content

Introduction: Review of power switching devices i.e. Thyristor, GTO, BJT, MOSFETS and IGBT. Triggering techniques and protection circuits. Phase controlled rectifier configurations: Control of output voltage and reduction of harmonics, multipulse rectifiers and unity power factor rectifiers. Choppers: Classifications of choppers, Chopper configurations types, choppers analysis and design, reduction of harmonics. AC controllers and Cyclo-converters: Line commutated and PWM inverters, reduction of harmonics. Advanced Solid State Devices & Systems: STATCOM, SVC, SMC and UPS.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Able to decide about choice of power electronic devices for design and implementing practical power electronic circuits.

CO2: Able to describe Operation of AC, DC Power Electronic Converters under variety of operating conditions.

CO3: Apply principles and tools to Classify various AC & DC Converters for industrial Applications.

CO4: The students will be able to understand use of advanced power electronic devices in modern FACTs systems.

Books and References:

1. Thyristors Power Controllers by Dubey, Doradla, Joshi and Sinha, New Age Publishers.
2. Power Electronics by Dr. M.H. Rashid, Pearson International Publishers.
3. Power Electronics (Converter, Applications & Design) by Ned Mohan, T. M Undeland & W. P. Robbin, Wiley India Publishers.
4. Recent Advances in Semiconductor Devices by B. K. Bose, Prentice Hall Publishers.
5. Power Electronics by P S Bhimbhra, Khanna Publisher.

Course Name: **High Voltage Engineering**
Course Code: **EE-762**
Course Type: **Program Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the physical high voltage phenomena and their impact in HV Equipments.
- To introduce the fundamental concepts relevant to high voltage insulations and their characterization.
- To enable the students, understand impact of various factors during design stage for safer use of high voltage systems.
- To impart knowledge about various configurations for generation and measurement procedures concerning application of high voltages in field/sites as per standards.

Course Content

Introduction, Introduction: Levels of voltages, Electrical Insulation and Dielectrics, Importance of Electric Field Intensity in the Dielectrics, Types of Electric Fields, Degree of Uniformity of Fields (Schwaiger Factor), Stress Control, Gaseous Dielectrics, Insulation properties of atmospheric air and SF6, Related ionization Process, Properties of vacuum, Related ionization Process, Development of Electron Avalanche, Breakdown Mechanisms, Townsend's Mechanism, Streamer Mechanism, Breakdown in Uniform Fields (Paschen's Law), Breakdown of gaseous dielectrics in Weakly Non-uniform and the limiting value of η, Development of 'Partial Breakdown' (PB) in Extremely Non-Uniform Fields, Breakdown characteristics' in air with stable PB (corona) applications of Risk and Reliability Tools ,Application of Risk analysis tools to at least three different category of electrical power system network problems based Case Studies concerning use of reliability engineering in real life electrical equipment risk analysis from estimating life of equipment's in substations of an electrical utility. Liquid and Solid Dielectrics, classification and Properties of Liquid Dielectrics, Classification and Properties of Solid Dielectrics, Permittivity and Polarization in Dielectrics, Insulation Resistance, Conductivity and Losses in Dielectrics, Surface discharges in Solid and Liquid Dielectrics, Measurement of Intrinsic Breakdown in solid dielectrics, Thermal and other Breakdown Mechanisms in extremely non-uniform fields, Comparison of the development of breakdown in extremely and weakly non-uniform fields, time lag in breakdown in solid as well as liquid dielectrics. Methods of generation of Power Frequency high test voltages, Transformers in Cascade, Resonance Transformers, Generation of high test dc voltage, Voltage Multiplier Circuits and Ripple Minimization, Sources of over voltages and Standard Lightning and Switching wave shapes, Impulse Voltage Generator, Analysis of Single Stage Circuit, Multistage Impulse Generator Measurement of High Test Voltages i.e. Peak High Voltage measurement techniques, Sphere gap; Effects of earthed objects and atmospheric conditions, Calibration needs of HV equipment's, Various test standards used for precise measurement of HV Impulse, HV DC and HV Impulse Voltage tests. Non-destructive High Voltage Testing and Quality Control, Measurable properties of dielectrics, Measurement of Dielectric properties with Schering Bridge and Mega-ohm meter, Partial Breakdown (PB) Measurement Techniques in Dielectrics/ Equipment. Insulation Coordination and Over Voltages in Power Systems Over voltages and Basic insulation level design.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify role of high voltage insulations and able to understand impact of HV DC, HV AC and Impulse voltages.
CO2: Describe contribution of surface discharges and arcing which if ignored can lead to failure of HV system.
CO3: Apply design principles of generation, measurements of all kind of high voltage waveforms in type tests of HV equipments.
CO4: Assess the role of insulation co-ordination and other performance parameters affecting safer application of High Voltages.

Books and References

1. High Voltage Engineering by M. S. Naidu and V. Kamaraju, Tata McGraw Hill.
2. High Voltage Engineering by E. Kuffel and M. Alldullah, Pergamon Press, Oxford.
3. High Voltage Engineering by E. Kuffel and Zaengal, Butterworth-Heinemann.

Course Name: **Solid State Control of Drives**
Course Code: **EE-724**
Course Type: **Programme Elective-IV**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives:

- To impart knowledge about the dc motor drives and its control.
- To introduce the fundamental concepts relevant to induction motor synchronous motor drives and their various control methods.
- To enable the students to understand the concepts of fractional horse power drives and its applications.

Course Content

Controlled Rectifier fed DC motor, Chopper fed DC motor, Modeling of drive elements – Equivalent circuit, transfer function of self, separately DC motors; Linear transfer function model of power converters; sensing and feedback elements – closed loop speed control – current and speed loops, P, PI and PID Controllers – response comparison. Simulation of converter and chopper fed dc drive. VSI & CSI inverters, Operation of induction motors from voltage and current source inverters. Scalar and vector control of induction motor, direct torque control of induction motor, Dynamic Modeling of Induction Machines –Field oriented control of induction machines – Theory – DC drive analogy – Direct and Indirect methods – Flux vector estimation using voltage model and current model equations – merits and demerits. Need for leading PF operation - open loop VSI fed drive - group drive applications. Self-control - margin angle control - torque angle control - power factor control - simple design examples - Closed loop speed control scheme with various power controllers - starting methods - brush less excitation systems. Classification of FHP drives, Brushless DC motor drive, permanent magnet drives-working principle, control and its applications.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify suitable solid-state control scheme for dc motor for particular application.

CO2: Describe the various control methods of induction motor drives.

CO3: Apply principles and algorithms described in CO2 to induction motor based on application.

CO4: Assess the suitability of FHP drive for certain application.

Books and References

1. Electric Motor Drives by R. Krishnan, PHI.
2. Control of Electrical Drives by Werner Leonhard, Springer.
3. Power Semiconductor Controlled Drives by G. K. Dubey, Prentice Hall.
4. Power Semiconductor Drives by S. B. Dewan, G. R. Slemon, A. Straughen, John Wiley.

Course Name: Distributed Generation and Microgrid
Course Code: EE-726
Course Type: Programme Elective-IV

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To develop a conceptual introduction to various distributed generation systems.
- Investigate the technical challenges of Distributed Generation technologies.
- To find optimal size, placement and control aspects of DGs.
- Design the microgrid architectures and its control operation.

Course Content

Modern Power System: Generation - Transmission - Distribution - Loads - Introduction to Distributed Generation (DG) - Technologies of DG - IEEE 1547- Solar photovoltaic generation - wind energy – Wind power plants - Microturbines - Fuel Cell - Storage Systems - batteries, fly-wheels, ultracapacitors – unit sizing of DGs - Case studies, Penetration of DGs Units in Power Systems - Integration of DGs Units in Distribution Network -Modern Power Electronics for DGs Applications – multiple and single input dc-dc converters - ac-dc and dc-ac converters - Technical restrictions - Protection of DGs - Economics of DGs –Pricing and Financing framework for DG units - Optimal placement of DGs - Case studies, Introduction to Microgrids - AC and DC microgrids - Operational Framework of Microgrids - anti-islanding schemes - Distribution Management System (DMS) - Microgrid System Central Controller (MGCC) – Local Controllers (LC) - Economic, environmental and operational benefits of Microgrids in a distribution network - Demand Response Management in Microgrids - Business Models and Pricing Mechanism in Microgrids - Interconnection of Microgrids.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand various distributed generation systems and their application in distribution system.

CO2: Design and develop modern systems for the upkeep of pollution free environment.

CO3: Utilize modern tools for modeling, analyzing and solving electrical and electronics engineering problems.

CO4: Ability to develop solutions for real-life electrical engineering problems.

Books and References

1. Renewable Energy Sources by J.N. Twidell & A. D. Weir, University press, Cambridge.
2. Solar Energy -Principles of Thermal Collection and Storage by S. P. Sukhatme, Tata McGraw-Hill, New Delhi.
3. Principles of Solar Engineering by F. Kreith, and J. F. Kreider, Mc-Graw-Hill Book Co.
4. Direct Energy Conversion by S.L. Soo, Prentice Hall Publication.
5. Fuel Cell Systems by James Larminie, and Andrew Dicks, John Weily & Sons Ltd.
6. Wind Energy Explained by J. F. Manwell, J. G. McGowan, A. L. Rogers, John Weily & Sons Ltd.
7. Power generation engineering aspects by E.J. Womack, Chapman and Hall Publication.
8. Non-Conventional energy Sources by G.D. Rai, Khanna Publications, New Delhi.
9. Distributed Generation- Induction and Permanent Magnet Generators by Loi Lei Lai, Tze Fun Chan, IEEE Press, John Wiley & Sons, Ltd., England.
10. Microgrid: Architecture and control by N. Haziargyriou, Wiley-IEEE press.

Course Name: Signal Conditioning and Data Acquisition
Course Code: EE-728
Course Type: Programme Elective-IV

Contact Hours/Week: **4L** | Course Credits: **04**

Course Objectives

- To impart knowledge about the signal conditioning
- To introduce the concepts of analog to digital conversion and vice versa and implementation of conditioning circuits
- To enable the students to understand data acquisition systems and telemetry.

Course Content

Signal Conditioning: Introduction, amplification, instrumentation amplifies, Optical amplifiers, A.C.& D.C. amplifiers, Operational amplifier specifications, operational amplifier circuits in instrumentation, Adder, inverter, subtractor, integrator, differentiator, logarithmic converter, Differential amplifier, Modulator-Demodulators, filters, types of filters, low pass, band pass, bridges, current sensitive bridge circuit, Voltage sensitive bridge. Clipping and clamping circuits. A/D & D/A Conversion Techniques: Resolution and Quantization, Aperture time, Sampling D/A Converters, A/D conversion techniques- successive approximation, resistor method, voltage to time A/D converter, Voltage to frequency converter techniques. Dual flow integration technique, Sample and hold circuit. Introduction to Data Acquisition System: Instrumentation systems, types of instrumentation systems, components of an Analog-Data-acquisition system, uses of data acquisition system, use of recorders in digital system, Digital recording systems, input conditioning equipment. Digitizer, Multiplexer (TDM, FDM). Land line telemetry, R F telemetry. Transmission channels. Modulation methods. Harmonic Analysis of Periodic Signals: Fundamentals of Fourier analysis, Practical harmonic analysis using a wattmeter.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understanding of basic concept of signal conditioning and data acquisition.
CO2: Describe the basic circuits used in realizing the signal conditioning.
CO3: Implementation of analog to digital conversion and signal conditioning circuits.
CO4: Performance Comparison of different data telemetry schemes.
CO5: Application of signal conditioning methods and data acquisition systems to practical problems.

Books and References

1. Measurement systems- Application and design by E.O. Doebelin, Tata McGraw Hill.
2. Electronic measurement and instrumentation by Oliver & Cage, McGraw Hill.
3. Microprocessors & Interfacing by Douglas V, Tata McGraw Hill.
4. Operational amplifiers and linear Integrated circuits by R.F. Coughlin & Driscoll, PHI, New Delhi.
5. Microprocessors with Applications in Process Control by S.I. Ahson, Tata McGraw Hill.
6. Electrical Measurements: Fundamentals, Concepts, Applications by Martin U Reissland, New Age International Publishers.

Course Name: **Microprocessor Based Instrumentation System**
Course Code: **EE-745**
Course Type: **Programme Elective-IV**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the fundamentals for microprocessor-based instrumentation systems.
- To introduce the basic concepts relevant to identify signal conditioning circuits for microprocessor-based instrumentation systems.
- To enable the students to understand the interfacing of various peripheral devices and signal conditioning issues for a given problem/application.

Course Content

Microcontroller/Microprocessor an overview: Basic differences and similarities between Microprocessor and Microcontroller. Introduction to various Microcontrollers, Difference between 8-bit / 16-bit, RISC / CISC, Concept of pipelining. Introduction to 8051 Microcontroller: Intel 8051 history, Pin diagram of 8051, 8051-architecture, Registers, Timers Counters, Flags, Special Function Registers, DPTR, PC, PSW, SP etc. Additional features in 8052, Addressing Modes, Data types and Directives, Jump, Loop and Call instructions Arithmetic instructions, and their simple programming applications. Microcontroller/microprocessor-based Instrumentation: Interfacing with LEDs, Seven Segment, LCD, Sensors, ADC, DAC, Stepper Motor, Relays etc., Case studies based on Microcontroller/ microprocessor.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understanding of the basic instrumentation systems and microprocessor-based systems and signal conditioning circuits.

CO2: An idea about the evolution of microprocessors/microcontrollers.

CO3: Understanding of various types of signal conditioning circuits.

CO4: Understanding of the interfacing of ADC, DAC, S/H, and sensors/transducers to microprocessor/ microcontroller using peripheral devices.

Books and References

1. Microprocessor and Interfacing (Programming and Hardware) by Douglas V. Hall, TMH, India.
2. Fundamentals of microprocessors and microcomputers by B. Ram, Dhanpat Rai Publication.
3. Microprocessor, Microcomputer and their Applications by A.K. Mukhopadhyay, Narosa.
4. Microprocessors with Applications in Process Control by S.I. Ahsan, TMH India.
5. Microprocessors Comprehensive Studies by Naresh Grover, Dhanpat Rai & Co.
6. Transducers in Instrumentation by D. V. S. Murthy, Prentice Hall.

Course Name: Electrical Apparatus Diagnostic Lab-II
Course Code: EE-664

Contact Hours/Week: **4P** Course Credits: **02**

Course Objectives

- To provide skills for carry out proper connections & take measurements on equipments related with condition assessment tests on power transformers
- To provide skills for assessing healthiness of electrical earthing mat
- To enable the students, learn handle safety norms and exercise precautions while working in field

List of Experiments

1. To measure the earth resistance by 3 probe method using Digital Earth Resistance Tester
2. To measure the resistivity of soil of ground by 4 probe method using Digital Earth Resistance Tester
3. To determine Flash Point of a sample of any liquid dielectric
4. To study & determine moisture contents in a sample of any liquid dielectric by a portable equipment using DOMINO test set
5. To investigate live line loading level using GUI based Thermo graphic camera on any operational electric power equipment like power transformer
6. To study and measure mechanical deformation in the windings by using SFRA (Sweep Frequency Response Analyzer) Test set
7. To study & carry out capacitance & tan delta measurements in respect of winding & bushings of power transformer in a substation
8. To study & determine degradation contents of paper in a given sample of liquid dielectric by using HPLC (High Performance Liquid Chromatography)

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.*

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify and interpret health condition of the dielectric of power transformer / electrical machine located in a substation

CO2: Design and develop condition assessment modules for ensuring trouble free operation of power equipments as well as earthing mat.

CO3: Develop strategy to prevent catastrophic failure and safety of power apparatus located in a substation.