Master of Technology

In

Electrical Engineering (Condition Monitoring of Power Apparatus)

Course Structure & Syllabus

Department of Electrical Engineering National Institute of Technology HamirpurHamirpur (HP) – 177005, India

Course Structure of M. Tech. in 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	Advanced 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	Computer-aided Design of Power Transformers	4	0	0	4	4
2	EE-662	Electrical Equipment Health Assessment	4	0	0	4	4
3	EE-663	Digital Protection of Power Apparatus	4	0	0	4	4
4	EE-7MN	Programme Elective-III	4	0	0	4	4
5	EE-7MN	Institute Elective	4	0	0	4	4
6	EE-664	Advanced Electrical Apparatus Diagnostic Lab-II	0	0	4	4	2
	Total		**20**	**0**	**4**	**24**	**22**

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

SEMESTER- III

Sr. No.	Course No.	Course Name	Hours/week	Credit
1	EE-798	M.Tech. Dissertation	--	18
	Total		**--**	**18**

SEMESTER- IV

Sr. No.	Course No.	Course Name	Hours/week	Credit
1	EE-799	M.Tech. Dissertation	--	18
	Total		**--**	**18**

Total Credit of the Programme = 80

Annexure

List of Programme Electives

Programme Elective-I:	**Common to all Streams of M. Tech**
EE-711	AI Techniques and Applications
EE-712	Optimization Techniques
EE-713	Genetic Algorithm and Evolutionary Programming
EE-714	PLC and SCADA Systems

Programme Elective-II:	**Common to Streams of M. Tech in Electrical Engineering (Power system) & M. Tech in Electrical Engineering (Condition Monitoring of Power Apparatus)**
EE-721	Solid State Devices and Converters
EE-722	Solid State Control of Drives
EE-723	Energy Auditing & Management
EE-724	Advanced High Voltage Engineering
EE-725	Distributed Generation and Microgrid

Programme Elective-III:	**M.Tech in Electrical Engineering (Condition Monitoring of Power Apparatus)**
EE-771	Risk and Reliability Engineering
EE-772	Testing and Maintenance of Electrical Power Apparatus
EE-773	Signal Conditioning and Data Acquisition
EE-774	Microprocessor Based Instrumentation System
EE-775	Condition Monitoring and Control of Renewable Energy Systems
EE-776	Condition Monitoring of Power Electronic Converters

List of Institute Electives

Course No.	Course Name
EE-701	Elements of Power Engineering
EE-702	Evolutionary Programming and Genetic Algorithms
EE-703	Distributed Generation Technology
EE-704	Optimization Techniques and Applications
EE-705	Electrical Vehicle Technologies
EE-706	Elements of Control Engineering

First Semester

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: Types of cooling and cooling arrangements, propeller fans and oil pumps, flow indicators. 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.

Text Books

1. S. V. Kulkarni, S. A. Khaparde, "Transformer Engineering Design and Practices," Marcel Dekker Inc., 2000.
2. BHEL (Bhopal), "Transformers," Tata McGraw Hill. 2003

Reference Books

1. James Harlow, "Electric power transformer engineering," CRC Press, 2007.
2. K. R. M. Nair, "Power and Distribution Transformers: Practical Design Guide," CRC Press; 1st edition, 2021.

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, HV phenomena, and technology.
- To understand functional principles, HV testing and issues linked with performance of HV systems practices during real time field operations including normal and accelerated aging.
- To understand diagnostics methods for protection of high voltage apparatus and similar assets.

Course Content

Introduction to HV Diagnostic Techniques: Overview of insulation materials and systems, Properties of insulating materials (e.g., dielectric strength, thermal conductivity), Factors affecting insulation life expectancy and ageing mechanisms, Introduction to diagnostic techniques for insulation condition assessment, Introduction to dielectric losses, ageing, and life expectancy, Basics of outdoor insulation materials and diagnostic techniques. Insulation Systems and Testing: Insulation system in practice, Dielectric losses and ageing mechanisms, AC and impulse voltage flashover studies, RIV and Corona Studies on insulator strings, High voltage testing techniques, Dry, wet, and pollution testing, High current and composite stress testing. Insulation Failure Mechanisms: Dielectric formalism and equivalent circuits, Intrinsic dielectric 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 and statistical models. Diagnostics and Condition Monitoring for an Electrical Power Apparatus: Need for diagnostics and condition monitoring, On-line/on-site testing techniques, Diagnostic tests, impulse test and neutral current method, Digital techniques and data acquisition principles, Winding structure and natural frequencies, Methods for fault identification and diagnostics, Partial Discharge (PD) Measurement and Analysis: Calibration of PD measurement systems, Digital PD measurement techniques, PD as a diagnostic tool, PD pattern recognition, Noise reduction methods in PD measurement. Residual Life Assessment and Breakdown Voltage Testing: Sweep Frequency Response Analysis (SFRA) test on transformers, Breakdown voltage test, Dissolved Gas Analysis (DGA) for fault identification, Case studies and practical applications, Case studies demonstrating the application of DGA in transformer diagnostics, Significance of hands-on training and field visits. Advanced Diagnostic Techniques: Introduction to AI and ML in HV diagnostics, Advanced data analysis techniques, Practical applications and case studies, Overview of advanced diagnostic software and tools used in HV diagnostics for Power Apparatus, future trends in area of HV Diagnostics, IOT systems.

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.

Text Books

1. Naidu, M.S. and Kamaraju, V., “High Voltage Engineering,” 4th, edition, Tata McGraw-Hill, New Delhi, 2008.
2. H. M. Ryan, Petr Pregrinus, “High Voltage Engineering and Testing,” Issue 17 of Institution of Electrical Engineers Publication Series, 1994.

Reference Books

1. Whitehead S, “Dielectric Breakdown of Solids,” Oxford University Press, 1953.
2. M. Khalifa, Dekker, “High Voltage Engineering: Theory & Practice,” 2^{nd} edition, CRC Press, 2018.
3. Ravindra Arora, Bharat Singh Rajpurohit, “Fundamentals of High-Voltage Engineering,” Wiley Publication, 2019.

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 selection 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, secondary sensors temperature sensors, pressure sensor, flow sensors, level sensor, acceleration sensor, torque measurement, synchro, resistive sensors, strain gauge, thermistors, magneto-resistors, light dependent resistors, Potentiometers, Resistive Temperature Detectors (RTDs), Resistive Hygrometers. Signal conditioning for resistive sensors: measurement of resistance, voltage dividers, Wheatstone bridge etc. Applications of Sensors: Self-generating sensors, thermoelectric, piezoelectric, pyrometer, photovoltaic sensors, capacitive sensors, inductive sensors, dissolved oxygen sensor, digital sensor encoder, liquid and gas chromatography, photo acoustic spectroscopy, ultrasonic sensor, ultra-high frequency sensors, optical-fibre sensors, smart sensors, application of these sensors in condition monitoring area. Signal conditioning Circuits: Analog signal conditioning, signal-level changing, filtering and impedance matching, passive circuits, divider circuit, bridge circuits, operational amplifiers, characteristics, Op amp circuits in instrumentation, voltage follower, precision rectifiers, differential amplifier, instrumentation amplifier, active filters, current-to-voltage converter. Digital Signal Conditioning: Review of digital fundamentals, buses and tri-state buffers, comparators, digital-to-analog converters (DAC), analog-to-digital converters (ADCs), sample and hold circuits, multiplexer and de-multiplexer, decoder and encoder, programmable logic controller, Interfacing sensors and transducers with microprocessors/microcontrollers
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Understanding sensors and transducers and to know about the basic instrumentation systems and signal conditioning circuits. CO2: Develop 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 the interfacing of ADC, DAC, S/H, sensors, transducers to microprocessor, microcontroller using peripheral devices.
Text Books 1. J. P. Bentley, "Principles of Measurement Systems," Wiley, 4th Edition, 2005. 2. R. E. James and Q. Su, "Condition Assessment of High Voltage Insulation in Power System Equipment," IET Power and Energy Series 53, 2008. 3. D. V. S. Murthy, "Transducers and Instrumentation," Prentice Hall, 2nd Edition, 2008. **Reference Books** 1. S. M. Sze, "Semiconductor Sensors," Wiley, 1994. 2. E. O. Doebelin, "Measurement Systems: Application and Design," McGraw Hill, 5th Edition, 2004.

3. John G. Webster, "Analog Signal Processing," Wiley Eastern Publication, 1998.
4. Ramon Pallas-Areny and John G. Webster, "Sensors and Signal Conditioning," Wiley, 2nd Edition, 2000.

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

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

Course Objectives

- To provide hands on skills for carrying out field tests on various HV equipment's and perform each test by ensuring availability of needful tools around them.
- To enable students understand make connections, take measurements by using diagnostic equipment.
- To provide skills for assessing healthiness of various dielectrics / HV Systems.
- To enable students to learn use of IS /IEC Safety Standards/ norms.
- To learn about various precautions while working in Diagnostic Lab.

List of Experiments

1. To find the dielectric breakdown Voltage of a given sample of Solid Dielectrics i.e Insulation paper or insulation sheet or a Pressboard sample.
2. To find the dielectric breakdown voltage of a given sample of liquid Insulation dielectric under different electrode spacings.
3. To study Flash point of a given sample of an oil filled Transformer liquid dielectrics and ascertain electrical health under various conditions.
4. To find Capacitance, 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 incipient faults in a sample of oil filled power transformer by using Dissolved Gas Analyzer set and ascertain fault level by using various methods.
8. To carry out air insulation breakdown studies by using uniform and non-uniform electrodes in HV Lab, by using 200KV HVAC Power frequency test set.
9. To determine sludge contents in a given sample of insulation oil/Ester Dielectrics.
10. To investigate dielectric breakdown studies by using 280KV HVDC / HV Impulse tests.

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 various solid insulations as well as liquid dielectrics used in power transformer / electrical machines located in a substation.

CO2: Design and develop strategies towards assets management-based scheme for ensuring trouble free operation of power station electrical equipment.

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

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.
- To inculcate critical thinking about what specialty makes humans intelligent, and how computer scientists are designing computers to act smartly or human beings.

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. Learning Rules: Biological neuron, mathematical model, supervised and unsupervised learning, neuron learning rules, feed-forward and feedback neuron networks. Artificial Neural Networks: 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 and their applications.

CO2: Able to apply these techniques in different fields, 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.

Text Books

1. N. P. Padhy, "Artificial Intelligence and Intelligent Systems," Oxford University Press.
2. S. Rajasekaran and G. A. V. Pai, "Neural Networks, Fuzzy Logic and Genetic Algorithm Synthesis and Applications," PHI New Delhi.

Reference Books

1. C. Lin and G. Lee, "Neural Fuzzy Systems," Prentice Hall International Inc.
2. D. E. Goldberg, "Genetic Algorithms in Search Optimization & Machine Learning," Addison-Wesley Co., New York.
3. B. Kosko, "Neural Networks & Fuzzy Systems: A Dynamical Systems Approach to Machine Intelligence," 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: Historical Development; Engineering applications of Optimization; Objective function; Constraints and Constraint surface; Classification of optimization problems based on nature of constraints, structure of the problem, deterministic nature of variables, separability of functions and number of objective functions. Linear Programming: Standard form of linear programming (LP) problem; Canonical form of LP problem; Assumptions in LP Models; 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. Classical Optimization: Stationary points - maxima, minima and saddle points; Functions of single and two variables; 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. Unconstrained Minimization Methods: unimodal function, exhaustive search, dichotomous search, Fibonacci method, golden section method, multivariable unconstrained minimization, grid search method, univariate method, Hooke and Jeeves' method, Powell's method, steepest descent method, conjugate gradient method, newton's method, quasi-newton methods. Constrained Optimization Techniques: Sequential linear programming, Indirect methods, basic approach to the penalty function method, interior penalty function method, exterior penalty function method, augmented LaGrange multiplier method. 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, relevant examples.

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.

Text Books

1. S. S. Rao, “Engineering Optimization: Theory and Practice,” New Age International, New Delhi.
2. S. Chandera, Jaydeva, and A. Mehta, “Numerical Optimization with Applications,” Narosa.

Reference Books

1. E. K. P. Chong, and S. H. Zak, “An Introduction to Optimization,” John Wiley.
2. M. C. Joshi and K. M. Moudgalya, “Optimization Theory and Practice,” 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 related to 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 fundamentals and applications 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 bits required for a variable, GA's operators, crossover and mutation, roulette wheel method for selection process, cumulative probabilities, basic flow chart, GAs for optimization with detailed 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: GA's applications 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 principles described in CO2 to explain various problems.
CO4: Assess the results obtained by solving above problems.

Text Books

1. M. Mitchell, "An Introduction to Genetic Algorithms," MIT Press, 1998.
2. A. E. Eiben, "Introduction to Evolutionary Computing," Springer-Verlag Berlin and Heidelberg.
3. N. P. Padhy, "Artificial Intelligence and Intelligent Systems," Oxford University Press.
4. Z. Michalewicz, "Genetic Algorithms, Data Structures and Evolution Programs," Berlin: Springer-Verlag.

References Books

1. M. Chis, "Evolutionary Computation and Optimization Algorithms in Software Engineering: Applications and Techniques," IGI Global publishers.
2. D. E. Goldberg, "Genetic Algorithms in Search-Optimization and Machine Learning," Addison-Wesley.

Course Name: PLC and SCADA Systems
Course Code: EE-714
Course Type: Programme Elective-I

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

Course Objectives

- Understand the role and benefits of automation in industries.
- Master PLC systems, including their types, components, and programming languages.
- Grasp analog operations and PID control methods, including tuning and implementing closed-loop control systems.
- Explore SCADA systems, including architecture, communication methods, and applications in industrial control and monitoring.

Course Content

The role of automation in industries, benefits of automation, necessity of PLCs, history and evolution of PLCs, types of PLCs, overall PLC system, CPU architecture, memory organization, and power supply modules. Programming languages for PLCs, including ladder diagram, structured text, and function block diagram. Developing ladder logic for various industrial applications, analog PLC operation, PLC analog signal processing, PID principles, and typical continuous process control curves. Detailed study of simple closed-loop systems, closed-loop systems using Proportional, Integral, and Derivative (PID) control, PID modules, PID tuning methods, and motor controls including variable frequency drives (VFDs). Comprehensive coverage of PLC applications in manufacturing, and process control. Introduction to Supervisory Control and Data Acquisition (SCADA) systems, definitions, and history. SCADA system architecture, including Human-Machine Interfaces (HMI), Master Terminal Units (MTU), Remote Terminal Units (RTU), and communication means such as Ethernet, serial, and wireless. Desirable properties of SCADA systems, including reliability, scalability, and security. Advantages, disadvantages, and applications of SCADA in various industries such as power, water treatment, and oil and gas, functions and features of SCADA systems, and an overview of SCADA protocols.

Course Outcomes

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

CO1: Comprehend automation's impact and essential PLC functions and components.

CO2: Acquire skills in PLC programming and ladder diagram creation.

CO3: Implement control techniques like PID in PLC systems.

CO4: Understand SCADA systems' architecture, protocols, and applications in industrial monitoring and control

Text books

1. Jon Stenerson, "Industrial Automation and Process Control", Prentice Hall, 2002.
2. Gary Dunning, " Introduction to Programmable Logic Controllers", Delmar Thomson Learning, 2001.
3. Frank D. Petruzella, "Programmable Logic Controllers", McGraw-Hill Education, 2010.
4. Ronald L. Kurtz, "Securing SCADA System", Wiley Publishing.
5. Stuart A Boyer, "SCADA supervisory control and data acquisition", 4th Revised edition, International Society of Automation.

Reference Books

1. Gordan Clark, Deem Reynders, "Practical Modern SCADA Protocols", Elesevier
2. Batten G. L., "Programmable Controllers", McGraw Hill Inc., Second Edition.

Course Name: **Solid State Devices and Converters**
Course Code: **EE-721**
Course Type: **Programme Elective-II**

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 to learn methods of PWM and harmonics mitigation.

Course Content

Introduction: Review of power switching devices i.e. Thyristor, GTO, BJT, MOSFETS and IGBT, Turn-on, Turn-off and V-I characteristics of different switching devices, snubber circuit, protection schemes, Gate driving circuits. Phase Controlled Rectifiers: Principles of operation of phase-controlled rectifiers (single/three phase) and their applications, performance parameters, single-phase half controlled/fully-controlled converter with R, RL, and RLE load, operation of three-phase fully-controlled converter with different types of loads, effect of source impedance, dual converters (single/three phase). Inverters: Introduction of inverter operation, classification of inverters and their applications, performance parameters, analyzing the performance of single-phase half bridge and full-bridge voltage source inverters with R, RL and RLE load, three-phase voltage source inverters-180-degree and 120-degree mode of operation, voltage control of single-phase inverters-single pulse width modulation, multiple pulse width modulation, sinusoidal pulse width modulation. Isolated and Non-isolated Converters: Basic Operation, waveforms, and modes of operation: buck and boost converter, interleaved converter, switched capacitor converter, Isolated dc-dc converter: basic operation, waveforms, and modes of operation, flyback converter, forward converter, push-pull, half, and full Bridge Converters. PWM Techniques of Converters: sinusoidal pulse width modulation in single phase inverters, choice of carrier frequency in SPWM, spectral content of output in bipolar and unipolar switching in SPWM, space vector PWM, output/input side filter requirements. Industrial Applications: Stabilized power supplies, uninterrupted power supplies, online UPS, offline UPS, high frequency online UPS, induction heating, active power conditioning.

Course Outcomes

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

CO1: Decide about choice of power electronic switching devices implementing practical circuits.
CO2: Describe operation of Power Electronic Converters under different operating conditions.
CO3: Apply principles and tools to classify various AC & DC Converters for industrial applications.
CO4: Analyze the operation of PWM techniques for harmonic mitigation.

Text Books

1. M. H. Rashid, “Power Electronics,” Pearson International Publishers.
2. N. Mohan, T. M Undeland, and W. P. Robbin, “Power Electronics Converter, Applications & Design,” Wiley India Publishers.
3. P. S. Bhimbhra, “Power Electronics,” Khanna Publishers.
4. M. D. Singh, K Khanchandani, “Power Electronics,” TMH.

Reference Books

1. D. Doradla, Joshi and Sinha, “Thyristorised Power Controllers,” New Age Publishers.
2. B. K. Bose, “Recent Advances in Semiconductor Devices,” Prentice Hall Publishers.
3. R. W. Erickson and D. Maksimovic, “Fundamentals of Power Electronics,” Springer Science.

Course Name: **Solid State Control of Drives**
Course Code**: EE-722**
Course Type: **Programme Elective-II**

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

Course Objectives

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

Course Content

Introduction to DC Motor Drive: Controlled Rectifier fed DC motor, Chopper fed DC motor, Modeling of drive elements – Equivalent circuit, transfer function of self and separately excited DC motors. Power Electronics Converters and Control: 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. Induction Machine Drive System: 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. Special Machine Drive Systems: Classification of FHP drives, Brushless DC motor drive, permanent magnet drives-working principle, control and its applications, DC drive analogy – Direct and Indirect methods, simple design examples.

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

Text Books

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

Reference Books

1. C. Richard, "Electric Drives and Electromechanical Systems: Applications and Control," Butterworth-Heinemann.
2. S. Seung-Ki, "Control of Electric Machine Drive Systems," Wiley-IEEE Press.

Course Name: **Energy Auditing & Management**
Course Code**: EE-723**
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.
- To promote critical thinking about assessing the energy efficiency of an entity/establishment.
- To bring out Energy Conservation Potential and business opportunities across different user segments.

Course Content

Introduction: 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. Tariffs and Auditing: 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. Efficiency Strategies: Electric motors energy efficient controls and starting efficiency- Motor Efficiency and Load Analysis- Energy efficient / high 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. 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. Energy Conservation Measures: Electric loads of Air conditioning & Refrigeration- - 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: Analyze different energy systems from a supply and demand perspective.
CO3: Recognize opportunities for rational use of energy in industrial applications.
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 the future.

Text Books

1. Y. P. Abbi and S. Jain, "Handbook on Energy Audit and Environment Management," TERI.
2. W. J. Younger, "Handbook of Energy Audits Albert Thumann," Terry Niehus.
3. G. Petrecca, "Industrial Energy Management: Principles and Applications," The Kluwer International Series -207.
4. A. J. Pansini, K. D. Smalling, "Guide to Electric Load Management," Pennwell Pub.
5. H. E. Jordan, "Energy-Efficient Electric Motors and Their Applications," Plenum Pub Corp.

Reference Books

1. W. C. Turner, "Energy Management Handbook," The Fairmont Press.
2. A. Thumann, "Handbook of Energy Audits," Fairmont Press.

3. A. Thumann and S. C. Dunning, “Plant Engineers and Managers Guide to Energy Conservation,” River Publishers.
4. “Recommended Practice for Energy Conservation and Cost-effective Planning in Industrial Facilities,” IEEE Bronze Book, USA.

Course Name: **Advanced High Voltage Engineering** Course Code: **EE-724** Course Type: **Programme Elective-II**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives • To impart knowledge about physical high voltage phenomena and their impact on HV systems. • To introduce the fundamental concepts relevant to high voltage insulations and their characterization. • To enable the students, understand about various factors that must be considered while design and safer use of high voltage systems.
Course Content
Introduction to High Voltage Classification: 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, Basics of Lightning Phenomenon, Charge formation in clouds, Wilson's theory, Simpson's theory, Mechanism of lightning, Stepped leader, Return stroke, Multiple strokes. Gaseous Dielectrics: Properties of atmospheric air, SF6 and 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 Fields and the limiting value of η, Development of 'Partial Breakdown' (PB) in Extremely Non-Uniform Fields, Breakdown Characteristics' in air with stable PB (corona). Liquid and Solid Dielectrics: Classification and Properties of Liquid and Solid Dielectrics, Permittivity and Polarization in Dielectrics, Insulation Resistance, Conductivity and Losses in Dielectrics, Partial Breakdown Phenomenon and on the Surfaces of Solid and Liquid Dielectrics, Breakdown in Liquid and Solid 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 and the Requirement of Time for Breakdown in Solid Dielectrics. Generation of High Test Voltages & Measurement Techniques: Methods of Generation of Power Frequency High Test Voltage, Transformers in Cascade, Resonance Transformers, Generation of High DC Voltage, Voltage Multiplier Circuits and Ripple Minimization, Sources of Over-voltages, Standard Lightning and Switching Wave Shapes, Impulse Voltage Generator, Analysis of Single Stage Circuit, Multistage Impulse Generator and their Triggering Methods., Measurement of High Test Voltages, Peak High Voltage Measurement Techniques, Sphere Gap Method, Effects of Earthed Objects and Atmospheric Conditions, Electrostatic Voltmeters, Principle and Construction, Potential Dividers-Types and Applications. Insulation Design and Coordination: Overhead line insulators, Insulator performance in polluted environment, EHV cable transmission – underground cables, High Voltage substations-AIS and GIS, Grounding of towers and substations, over voltages in power systems, Lightning and Switching over voltages, Insulation Co-ordination, and design of line insulation for power frequency voltage, lightning and switching over voltages. High Voltage Testing and Quality Control: Application of risk analysis tools to at least three different category of electrical power system network problems, Case studies concerning use of reliability engineering in real life electrical equipment, Risk analysis from estimating life of equipment in substations of an electrical utility.
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Identify role of high voltage insulations and their impact in implementing design of HV systems. CO2: Describe contribution of partial discharges and arcing which can lead to failure of HV systems. CO3: Apply principles of generation, measurements of all kind of high voltage waveforms in type tests of HV equipment. CO4: Assess the role of insulation co-ordination and other performance parameters affecting safer application of High Voltages.

Text Books

1. E. Kuffel, W. S. Zaengl, and J. Kuffel, “High Voltage Engineering fundamentals,” 2nd Edition, Newness (Oxford, Boston), 2000.
2. M. S. Naidu and V. Kamaraju, “High Voltage Engineering: Fundamentals,” 4th Edition, Tata McGraw-Hill, New Delhi, 2008.
3. R. Arora and W. Mosch, “High Voltage and Electrical Insulation Engineering,” Wiley-IEEE, 2011.

Reference Books

1. M. Abdel-Salam, H. Anis, and Abdel-Salamani, “High-Voltage Engineering: Theory and Practice,” 2nd Edition, CRC Press, 2001.
2. D. Kind and K. Freser, “High Voltage Test Techniques,” 2nd Edition, Newnes (Oxford, Boston).
3. S. Ray, “An Introduction to High Voltage Engineering,” Prentice Hall India, New Delhi, 2004.

Course Name: **Distributed Generation and Microgrid**
Course Code: **EE-725**
Course Type: **Programme Elective-II**

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

Course Objectives

- To provide 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 distributed generation technologies.
- Design the microgrid architectures and their control operation.

Course Content

Modern Power System: Generation, Transmission, Distribution, Loads, Introduction to distributed generation (DG), Technologies of DG, IEEE-1547. Distributed Generation Systems: 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 DG units in Power Systems, Integration of DG units in distribution network. Modern Power Electronics for DG 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, Microgrid system central controller, Local controllers, 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 applications.
CO2: Design and develop modern systems for the upkeep of pollution free environment.
CO3: Utilize tools for modelling, analyzing, and solving electrical and electronics engineering problems.
CO4: Develop solutions for real-life electrical engineering problems.

Text Books

1. J. N. Twidell and A. D. Weir, "Renewable Energy Sources," University Press, Cambridge.
2. S. P. Sukhatme, "Solar Energy - Principles of Thermal Collection and Storage," Tata McGrawHill.
3. F. Kreith and J. F. Kreider, "Principles of Solar Engineering," Mc-Graw-Hill.
4. S. L. Soo, "Direct Energy Conversion," Prentice Hall Publication.
5. J. Larminie and A. Dicks, "Fuel Cell Systems," John Wiley.

Reference Books

1. J. F. Manwell, J. G. McGowan, and A. L. Rogers, "Wind Energy Explained," John Wiley.
2. E.J. Womack, "Power Generation Engineering Aspects," Chapman and Hall Publication.
3. G.D. Rai, "Non-Conventional Energy Sources," Khanna Publications, New Delhi.
4. L.L. Lai and T. F. Chan, "Distributed Generation - Induction and Permanent Magnet Generators," IEEE Press, John Wiley & Sons, England.
5. N. Haziargyriou, "Microgrid: Architecture and Control," Wiley-IEEE Press.

Second Semester

Course Name: **Computer-aided Design of Power Transformers**
Course Code: **EE-661**
Course Type: **Core Course**

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

Course Objectives

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

Course Content

Introduction: Fundamentals and Principles of Design, Specifications, Output Coefficient, Importance of Specific Loading, Electrical Materials, Magnetic Circuit Calculations, Heating & Cooling, Standard Rating of Electrical Machines, General Design Procedure. Transformer Design End User 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: Complete Design of a 100 KVA transformer, Design of 630 KVA transformer, design of 5 MVA, 33/11 KV transformer. Modern Transformer Design: Evaluation of Transformer Technical Characteristics, Introduction, No-Load Loss Classification with Decision Trees and Artificial Neural Networks, No-Load Loss Forecasting with Artificial Neural Networks, Impedance Voltage Evaluation with Numerical Models. Transformer Design Optimization: No-Load Loss Reduction with Genetic Algorithms, Winding Material Selection with Decision Trees and Artificial Neural Networks, Transformer Design Optimization with Branch-and-Bound, Transformer Design Optimization with Genetic Algorithms, Some examples with programming/design of transformers.

Course Outcomes

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

CO1: Prepare the specifications and the technical details of Power Transformers.
CO2: To carry out detailed design of power transformers with varying ratings.
CO3: To design a power transformer with modern techniques.
CO4: To be able to accomplish the optimum design with conventional as well as metaheuristic techniques.

Text Books

1. Sawhney, A. K., "A Course in Electrical Machine Design," Dhanpat Rai and Co., 2016.
2. K M Vishnu Murthy, "Computer-aided design of electrical machines," BS publications, 2008.
3. T. A. Lipo, "Introduction to AC Machine Design," IEEE Press, Wiley Publications, 2017.

Reference Books

1. J. Pyrhonen, T. Jokinen, and V. Hrabovcova, "Design of Rotating Electrical Machines," John Wiley and Sons Inc., 2nd edition, 2013.
2. J. R. Hendershot and T. J. E. Miller, "Design of Brushless Permanent – Magnet Motors," Motor Design Books LLC, 2nd edition, 2010.
3. Pavlos S. Georgilakis, "Spotlight on Modern Transformer Design," Springer, 2009.

Course Name: **Electrical Equipment Health Assessment** 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 health condition monitoring practices for ensuring trouble free reliable operation in various electrical installations.
- To learn various tools of condition assessment for proper diagnosis of faults in a power apparatus.
- To derive basic mathematical expressions for analysis & characterization of electrical equipment insulation.
- To enable students to learn procedures to carry out health assessment studies for power apparatus.

Course Content

Introduction to Health Condition Monitoring: Condition Monitoring (in context of electrical systems), Periodic Based Maintenance and Condition Based Maintenance. Condition assessment modules. Characterization of Electrical Equipment Insulation Condition: Permittivity and capacitance in insulation, Resistance and insulation resistance measurements, Time constants in insulation, Dielectric dissipation factor, Partial discharge: sources, forms, effects, and detection, Modes of deterioration and failure of practical insulating materials, Dielectric losses and their significance, Ageing effects and damage due to partial discharge, Thermal stress and its impact on insulation, Overview of major requirements for electrical insulating materials, Concept of insulation design in electrical equipment. Health Condition Monitoring of Oil Filled Apparatus: Introduction, Chemistry of insulation oil, trends in newer liquid dielectrics, functions of transformer oil and causes of oil ageing, Control of oil ageing acceleration factors, transformer oil tests (e.g., power factor, moisture, neutralization number), Interpretation of oil test results as per national and International standards, Electrical testing of transformers (e.g., power factor, turns ratio, DC resistance), Insulation resistance test and leakage reactance test, Frequency response analysis and its use in transformer condition assessment, Partial discharge testing and interpretation, Transformer bushing diagnostics. Condition Monitoring of Rotating Electrical Machines: Overview of electric motor failures and preventive techniques, Methods of motor monitoring (e.g., current, temperature, vibration), MCSA using FFT and Wavelet technique, Starting strategies and soft starts for electric motors, lubrication, and cleaning techniques for motor maintenance, Advanced health monitoring techniques for electric generators, vibration monitoring in rotating electrical machines, Implementing Current monitoring tools for condition assessment for high energy density drives. Safety Norms as per IS/ ASTM/IEC Standards. Condition monitoring of cables and transmission systems, Advanced Topics in AI and ML for Condition Monitoring: Introduction to AI and ML applications in condition monitoring and diagnostics engineering, Data preprocessing techniques, Feature selection and extraction methods for condition monitoring data, SL, UL and RL applications, Predictive maintenance and Fault detection and classification using AI and ML techniques. Case Studies Demonstrating Application of Various Tools: Sample electrical health assessment studies for key substation equipment involving application of various tools, techniques employed in health condition monitoring practices, Concept of health condition index, Methods of its evaluation and prospective use to extend life of substation equipment and manage assets before any catastrophic failures.

Course Outcomes

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

- CO1: Identify various modes of failures of power equipment located in electric power sub-stations networks.
- CO2: Describe various diagnostic tests related with health condition assessment of power apparatus.
- CO3: Apply principles and tools to carry out health condition assessment studies related with power transformers.
- CO4: 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.

Text Books

1. B. K. N. Rao, “Handbook of Condition Monitoring,” Elsevier Science Publisher, 1998.
2. R.E James, “Condition Assessment of High Voltage Insulation in Power System Equipment,” IET, 2007.
3. P. J. Tavner, J. Penman, “Condition Monitoring of Rotating Electrical Machines,” IET, 2008.

Reference Books

1. Arni S.R. Srinivasa Rao, C.R. Rao, Steven Krantz , “Artificial Intelligence,” Elsevier Publications, 2023.
2. W.H. Tang, Q.H. Wu, “Condition Monitoring and Assessment of Power Transformers Using Computational Intelligence (Power Systems),” Springer Publications, 2011.

Course Name: **Digital Protection of Power Apparatus**
Course Code: **EE-663**
Course Type: **Core**

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

Course Objectives

- Gain knowledge of various digital protective schemes for transmission lines and power apparatus.
- Develop the ability to select and design appropriate instrument transformers tailored to specific protection scheme requirements.
- Acquire skills to realize numerical relays on hardware platforms.
- Learn to conduct thorough testing and ensure proper coordination of relays within power systems.

Course Content

Introduction: Art of relaying - Protective Relaying - Qualities of relaying, Definitions - Codes- Standards; Characteristic Functions; Classification – analog - digital- numerical; schemes and design-factors affecting performance –zones and degree of protection; faults-types and evaluation; Instrument transformers for protection. Digital Relaying: Basic elements of digital protection –signal conditioning- conversion subsystems- relay units-sequence networks-fault sensing data processing units- FFT and Wavelet based algorithms: least square and differential equation based algorithms travelling wave protection schemes; Relay Schematics and Analysis Over Current Relay-Instantaneous/Inverse Time – IDMT Characteristics; Directional Relays; Differential Relays- Restraining Characteristics; Distance Relays: Types Characteristics. Relay coordination- Relay setting calculations. Primary and backup protection, application and philosophy with applied relay engineering examples. Apparatus and System Protection: Digital Protection of power system apparatus – protection of generators – Transformer protection – magnetizing inrush current – Application and connection of transformer differential relays – transformer over current protection. Bus bar protection - line protection - distance protection–long EHV line protection - Power line carrier protection Motors protection; Pilot wire and Carrier Current Schemes; Reactor protection – Protection of boosters - capacitors in an interconnected power system. System grounding –ground faults and protection; Load shedding and frequency relaying; Out of step relaying; Reclosing and synchronizing. Advanced Protection Schemes: Integrated and multifunction protection schemes -SCADA based protection systems- Fault Tree Analysis; Testing of Relays- Field test procedures for protective relays. Adaptive relaying- AI & Fuzzy Based Protection, Intelligent Transmission Line Relaying Fault Detection.

Course Outcomes

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

CO1: Explain various digital protective schemes for transmission lines and power apparatus.
CO2: Select and design instrument transformers for a specific protection scheme design.
CO3: Realize numerical relays in hardware platform.
CO4: Conduct testing and coordination of relays.

Text Books

1. A.G.Phadke, James S.Thorp, "Computer Relaying for Power Systems," John-Wiley publication, 2nd edition, 2009.
2. Waldemar Rebizant , Janusz Szafran, and Andrzej Wiszniewski. "Digital Signal Processing in Power System Protection and Control," Springer Publication, 2011.
3. A.T.Johns and S.K.Salman, "Digital Protection for Power Systems," IEEE Power Series, 1997.

Reference Books

1. Latest IEEE Transactions papers on recent advancements in digital and adaptive relays; latest Digital relay manuals of ABB, Siemens etc.
2. Stanley H. Horowitz, Arun G. Phadke, and Charles F. Henville, "Power System Relaying," John Wiley

& Sons, 5th Edition, 2022.
3. D N Vishwakarma, Badri Ram, and Soumya R Mohanty, “Power System Protection and Switchgear,” McGraw Hill, 3rd Edition, 2022.

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

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

Course Objectives

- To empower students' skills to independently handle lab and field diagnostic equipment.
- To enable students to make proper connections, follow guidelines as per manual or SOP to take correct measurements by observing safety and diagnostic protocols.
- To provide skills for assessing healthiness of electrical earthing.
- To encourage students to learn skills of taking correct decisions to prevent accidents while working in field.

List of Experiments

1. To measure the earth resistance of electrode by 3 probe method using Digital Earth Resistance Tester.
2. To measure the resistivity of soil by visiting site of new/existing substation by 4 probe method using Digital Earth Resistance Tester.
3. To determine Dielectric Frequency Dependence Characteristics of windings of electric power apparatus.
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 health of any operational power equipment using GUI based Thermo-graphic camera.
6. To study mechanical integrity aspects in the windings of an electric apparatus in field 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 by using insulation analyzer.
8. To study & determine degradation contents in a given sample of liquid dielectric by using HPLC (High Performance Liquid Chromatography) test set.
9. To investigate performance and working of FTIR test set in ascertaining oxygen stability in a sample of oil filled transformer
10. To carry out failure analysis/equipment health investigations on any system/sub-system at a substation.

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 equipment as well as earthing.

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

Course Name: **Risk and Reliability Engineering**
Course Code: **EE-771**
Course Type: **Programme Elective-III**

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

Course Objectives

- To impart knowledge about the concept of reliability of physical high voltage equipment.
- To introduce fundamental concepts relevant to reliable design, reliable operation and safety of electrical equipment.
- 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 equipment.

Course Content

Introduction: 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 from user and condition assessment point of view. Reliability and Maintenance Analysis: 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 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.

Text Books

1. R. E. James and Q. Su, "Condition Assessment of High Voltage Insulation," IET Power and Energy Series 53, IET London, 2008.
2. E. Kuffel and W. S. Zaengl, "High Voltage Engineering: Fundamentals," Butterworth-Heinemann, 2nd Edition, 2000.

Reference Books

1. T. S. Ramu, "Reliability and Life Estimation of Power Equipment," New Age International Publishers, 2013.
2. Various Authors, "Statistical Techniques for High Voltage Engineering," IET Power and Energy Series 13, IET London, 1996.

Course Name: **Testing and Maintenance of Electrical Power Apparatus**
Course Code: **EE-772**
Course Type: **Programme Elective-III**

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 Content

Introduction: Overview of Electrical Preventive Maintenance and Testing, overview of testing and test methods, review of dielectric theory and practice, importance of electrical preventive maintenance, predictive maintenance techniques, electrical testing instruments and tools, safety procedures and best practices, documentation and record keeping, advancements in electrical maintenance technology. 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, Impact of temperature and humidity on test accuracy, safety protocols during DC testing, comparison of DC and AC testing methods, advanced DC testing equipment and tools, and common challenges and troubleshooting in DC voltage testing. 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 Testing: 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: Identify various kind of tests related with power equipment's located in electric power sub stations networks.
CO2: 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: Develop skill for using safe practices and prevent accidents, human loss, asset damage in event of fires, etc. in field operation despite precautions.

Text Books

1. Paul Gill, "Electrical Power Equipment Maintenance and Testing," CRC Press, 2nd Edition, 2009.
2. Charles I. Hubert, "Operating, Testing, and Preventive Maintenance of Electrical Power Apparatus," Prentice Hall, 2003.

Reference Books

1. James H. Harlow, "Electric Power Transformer Engineering," CRC Press, 3rd Edition, 2012.

2. J. Lewis Blackburn and Thomas J. Domin, "Protective Relaying: Principles and Applications," CRC Press, 4th Edition, 2014.

Course Name: **Signal Conditioning and Data Acquisition**
Course Code: **EE-773**
Course Type: **Programmme Elective-III**

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: Harmonic Analysis of Periodic Signals: Fundamentals of Fourier analysis, Practical harmonic analysis using a wattmeter, Harmonic distortion and its effects on signal quality, Methods for measuring harmonic distortion, Applications of harmonic analysis in power systems, Use of Fast Fourier Transform (FFT) in harmonic analysis, Harmonic filtering techniques, Software tools for harmonic analysis and simulation.

Course Outcomes

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

CO1: Understand basic concepts of signal conditioning and data acquisition.
CO2: Describe the basic circuits used in realizing the signal conditioning.
CO3: Implement analog to digital conversion using signal conditioning circuits.
CO4: Carry out Performance Comparison of different data telemetry schemes.
CO5: Apply signal conditioning methods and data acquisition systems to practical problems.

Text Books

1. E. O. Doebelin, "Measurement Systems: Application and Design," Tata McGraw Hill, 4th Edition, 2004.
2. Bernard Oliver and John M. Cage, "Electronic Measurement and Instrumentation," McGraw Hill, 1971.
3. Douglas V. Hall, "Microprocessors and Interfacing: Programming and Hardware," Tata McGraw Hill, 2nd Edition, 2006.

Reference Books

1. Robert F. Coughlin and Frederick F. Driscoll, "Operational Amplifiers and Linear Integrated Circuits," PHI, New Delhi, 6th Edition, 2001.
2. S. I. Ahson, "Microprocessors with Applications in Process Control," Tata McGraw Hill, 1984.
3. Martin U. Reissland, "Electrical Measurements: Fundamentals, Concepts, Applications," New Age International Publishers, 1989.

Course Name: **Microprocessor Based Instrumentation System**
Course Code: **EE-774**
Course Type: **Programme Elective-III**

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

Introduction: Overview of Microcontroller/Microprocessor, Basic differences and similarities between Microprocessor and Microcontroller. Introduction to various Microcontrollers, Difference between 8-bit /16-bit/32-bit, RISC/CISC processors, Concept of pipelining, Introduction to FPGA. Intel 8051 Microcontroller: Intel 8051 history, Pin diagram of 8051, 8051- architecture, Registers, Timers Counters, Flags, Special Function Registers, DPTR, PC, PSW, SP etc., Addressing Modes, Data types and Directives, Additional features in 8052, Intel 8096, PIC16F877. Instructions in Microcontrollers: Jump, Loop and Call instructions Arithmetic instructions, and their simple programming applications, Jump, Loop, Call, Arithmetic instructions, Introduction to development of a Microcontroller based system, Simple programming applications, Concept of PLC, Features and parts in a PLC unit. Microcontroller/Microprocessor-based Instrumentation: Interfacing with LEDs, Seven Segment, LCD, Sensors, ADC, DAC, Stepper Motor, Relays, Optocoupler etc., Case studies based on Microcontroller/ microprocessor, Case studies on Microprocessor/Microcontroller based systems.

Course Outcomes

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

CO1: Understand the basic instrumentation systems and microprocessor-based systems and signal conditioning circuits.
CO2: Develop an idea about the evolution of microprocessors/microcontrollers.
CO3: Understand various types of signal conditioning circuits.
CO4: Understand the interfacing of ADC, DAC, S/H, and sensors, transducers to microprocessor, microcontroller using peripheral devices.

Text Books

1. Douglas V. Hall, "Microprocessors and Interfacing: Programming and Hardware," McGraw-Hill, 1986.
2. B. Ram, "Fundamentals of Microprocessors and Microcomputers," Dhanpat Rai Publication, 2008.
3. A.K. Mukhopadhyay, "Microprocessor, Microcomputer and their Applications," Narosa Publishing House, 2006.

Reference Books

1. S.I. Ahsan, "Microprocessors with Applications in Process Control," TMH India, 1991.
2. Naresh Grover, "Microprocessors: Comprehensive Studies," Dhanpat Rai & Co., 2004.
3. D. V. S. Murthy, "Transducers in Instrumentation," Prentice Hall, 1995.

Course Name: **Condition Monitoring and Control of Renewable Energy Systems**
Course Code: **EE-775**
Course Type: **Program Elective-III**

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

Course Objectives

- To learn the control methods applied in renewable energy systems.
- To study the testing and monitoring of wind turbine systems.
- To learn the inspection and condition monitoring methods of solar and fuel cells.

Course Content

Introduction: Control Methods Applied in Renewable Energy Systems: Rectifier topologies, DC-DC converter, inverters for renewable energy, Control methods in Solar systems, control methods in wind systems, Control methods in fuel cells. Solar Photovoltaic Technology: Operation and Maintenance Methods in Solar Power Plants: condition monitoring system for solar plants based on thermography, Concentrating Systems, Different Solar power plants, Electricity generation cost, Safety Necessities, PV-specific signage and warning, Detailed visual inspection, Failure response, Diagnosing and Testing for Low Power Production, Solar power plant monitoring, reliability of photovoltaic installation, Remotely operated vehicle applications. Wind Energy Technology: Condition Monitoring and Maintenance Methods in Wind Turbines, Asset Management in maintenance of wind turbine, Maintenance Decision-Making Process Classification, Estimation of Deviations in the Wind Turbine Condition, condition indicators, Wind Turbines Risk Evaluation, testing for the evaluation of icing blades, Wind turbine gearboxes: Failures, surface treatments, testing of wind turbines using ultrasonic waves. PEM Fuel cells: Introduction to PEM fuel cells; Electrochemical reaction – thermodynamics and kinetics; Current-Voltage Expression; Fuel Cell Components; Fuel Cell Performance; Techniques for PEM Fuel Cell Testing and diagnosis - Lifetime/Durability Testing, Accelerated Testing, Electrochemical Impedance Spectroscopy, Current and Temperature Mapping, X-ray Imaging, and Neutron Imaging for Water Flow, Transmission Electron Microscopy, etc.

Course Outcomes

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

CO1: Apply the control techniques in solar, wind and fuel cell technologies.
CO2: Analyze the condition and monitoring of different components and testing of solar/PV systems.
CO3: Understand the different conditions of wind turbine system.
CO4: Evaluate the testing methods in fuel cells.

Text Books

1. Mayorkinos Papaelias, Fausto Pedro García Márquez, Alexander Karyotakis, "Introduction to Non-Destructive Testing and Condition Monitoring Techniques for Renewable Energy Industrial Assets," Elsevier and Butterworth-Heinemann, 2020.
2. Miguel A. Sanz-Bobi, "Use, Operation and Maintenance of Renewable Energy Systems," Springer, 2014.
3. Jianlu Zhang, Huamin Zhang, Jinfeng Wu, Jiujun Zhang, "PEM Fuel Cell Testing and Diagnosis," Elsevier, 2013.

Reference Books

1. C. S. Solanki, "Solar Photovoltaics: Fundamentals, Technologies and Applications," Prentice Hall India, 2nd Edition, 2011.
2. J.W. Twidell & A. Weir, "Renewable Energy Sources," EFN Spon Ltd., UK, 2006.
3. Detlef Stolten, "Hydrogen and Fuel Cells: Fundamentals, Technologies and Applications," Wiley, 2010.
4. San Ping Jiang, Qingfeng Li, "Introduction to Fuel Cells: Electrochemistry and Materials," Springer,

2022.

5. B. H. Khan, "Non-Conventional Energy Resources," The McGraw Hill.
6. Mayorkinos Papaelias, Fausto Pedro García Márquez, Alexander Karyotakis, "Non-Destructive Testing and Condition Monitoring Techniques for Renewable Energy Industrial Assets," Elsevier, 2019.

Course Name: **Condition Monitoring of Power Electronic Converters**
Course Code: **EE-776**
Course Type: **Program Elective-III**

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

Course Objectives

- To understand various failure mechanisms of power semiconductors.
- To gain knowledge about condition monitoring of different power semiconductor devices.
- To impart knowledge about failure mechanisms of capacitors.
- To develop skills for reliability analysis of power electronic conversion systems.

Course Content

Failure Mechanisms of Power Semiconductors: Aluminum reconstruction Bond fatigue, Die-attach fatigue and delamination Substrate cracking Bond-wire melting, Die-attach voiding, Aluminum corrosion, Latch-up, Avalanche breakdown, Partial discharge Electrochemical and silver migration, Dielectric breakdown, Time-dependent dielectric breakdown, Hot carrier injection, Competing failure mechanisms, Anomaly detection and remaining life prediction for power electronics-failure models, Data driven methods for life prediction. Condition Monitoring of Power Electronic Devices: IGBT failure- wear out/catastrophic, Thermal modeling of IGBT-analytic, numeric, and network models, Modeling of GaN devices for break down voltage assessment, IGBT Failure Mechanisms, On-state voltage drop monitoring for aging detection, Vibration and acoustic emission monitoring for mechanical integrity, High-temperature operation effects on GaN devices. Condition Monitoring of Capacitors in PEC System: Capacitors for DC-links in power electronic converters, Failure mechanisms and lifetime models of capacitors, Reliability-oriented design for DC links, Aging detection for capacitors, Condition monitoring of DC-link capacitors. Reliability Analysis and Data-Driven Condition Monitoring of PEC: Reliability analysis- methods and tools, reliability testing and robustness validation-qualitative and quantitative test methods, qualification testing, Case study- grid-connected solar inverter system.

Course Outcomes

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

CO1: Explain the possible failure mechanisms of various power electronic switches.
CO2: Explain the modeling of power electronic devices for condition monitoring.
CO3: Understand lifetime models of capacitors used in power electronic conversion systems.
CO4: Carryout reliability analysis of power electronic conversion systems with data-driven methods.

Text Books

1. H. S. Chung, H. Wang, et al., "Reliability of Power Electronic Converter Systems," IET, London, 2015.
2. A. Haque, et al., "Reliability of Power Electronic Converter for Solar PV Applications," IET, London, 2016.
3. A. Haque, et al., "Fault Analysis and its Impact on Grid-Connected Photovoltaic Systems Performance," Wiley-IEEE Press, 2017.

Reference Books

1. Brian Norton and Philip C. Eames, "Solar Energy Systems: Thermal, Photovoltaic and Hybrid Power", Academic Press, 2021.J.W. Twidell & A. Weir, "Renewable Energy Sources," EFN Ltd., UK, 2006.
2. Rolf P. Rüther, "Photovoltaics: Theory and Practice of Energy Conversion," Springer, 2016.

Institute Electives

Course Name: **Elements of Power Engineering** Course Code: **EE-701** Course Type: **Institute Elective**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives • To learn modelling, analysis, and operation of power systems. • To instill a practical knowledge of large-scale power system analysis. • To explore modern power system trends like smart grids distributed generation and microgrids.
Course Content
Basics of Power System: Basic structure and concepts of power system, significance of electrical energy, single-line diagram of a power supply network, working and applications of power transformer, distribution transformer and alternator. Introduction to load characteristics, various factors and power factor improvement. Power Generation and Distribution Systems: Sources of electric energy: wind, solar, hydro, thermal nuclear, battery energy storage systems, cogeneration, distributed Generation. General aspects, Kelvin's Law, AC and DC distribution systems, Calculation of feeder currents and voltages, distribution loss. Power Transmission System: Long length transmission line model, ABCD Parameters and T and π model representation, calculation of efficiency and voltage regulation, Ferranti effect, series and shunt compensation, surge impedance loading (SIL), introduction to underground cables and grading. Protective Relays: Basics of different types of relays, over current relay, IDMT relay, differential protection, distance protection of transmission lines through impedance, reactance and mho relay, comparison between distance relays, static relays. Power System Economics: Characteristics of generating units, Incremental Cost, Economic dispatch with and without losses using λ- Iteration Method. Modern Power Systems: Deregulated power systems, Smart grids, demand side management, microgrids - types of microgrids.
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Provide a solid understanding of the theoretical aspects of power systems. CO2: Understand different types of power generation systems. CO3: Understand the operation of power systems and various protection relays. CO4: Adapt to modern power system trends for industry relevance.
Text Books 1. C. L. Wadhwa, “Electric Power Systems,” New Age International, New Delhi. 2. D. P. Kothari and I. J. Nagrath, “Power System Engineering,” Tata McGraw Hill, New Delhi. **Reference Books** 1. S. S. Rao, B. Ravindernath, and M. Chander, “Switchgear and Protection,” Khanna Publishers. 2. J. J. Grainger and W. D. Stevenson, “Power System Analysis,” McGraw-Hill Education.

Course Name: **Evolutionary Programming and Genetic Algorithms**
Course Code: **EE-702**
Course Type: **Institute Elective**

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

Course Objectives

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

Course Content

Introduction: Basic concepts and definitions, artificial intelligence, genetic algorithms (GAs), evolutionary programming (EP). Evolutionary Programming: Initialization, Creation of offspring, Competition and selection, Gaussian random numbers, standard deviation, Difference between GAs and EP, basic algorithms, step by step procedure of evolutionary programming for optimization. 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. Applications: GAs and EP applications for economic power dispatch and optimal power 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.

Text Books

1. M. Mitchell, "An Introduction to Genetic Algorithms," MIT Press, 1998.
2. N. P. Padhy, "Artificial Intelligence and Intelligent Systems," Oxford University Press.
3. A. E. Eiben, "Introduction to Evolutionary Computing," Springer-Verlag Berlin and Heidelberg.
4. Z. Michalewicz, "Genetic Algorithms, Data Structures and Evolution Programs," Berlin: Springer-Verlag.

References Books

1. M. Chis, "Evolutionary Computation and Optimization Algorithms in Software Engineering: Applications and Techniques," IGI Global publishers.
2. D. E. Goldberg, "Genetic Algorithms in Search Optimization and Machine Learning," Addison-Wesley.

Course Name: **Distributed Generation Technology**
Course Code: **EE-703**
Course Type: **Institute Elective**

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

Course Objectives

- To impart knowledge about distributed generation technology.
- To introduce the modern power system, solar photovoltaic system, wind power system, and energy storage system.
- To enable students to understand how the solar photovoltaic, wind power, and energy storage system works.

Course Content

Modern Power System: Generation, Transmission, Distribution, Loads, Introduction to distributed generation, Technologies of distributed generation, IEEE-1547. Solar Photovoltaic System: Solar cell overview, Photon absorption at the junction, Solar cell construction, Types and adaptations of photovoltaics, Photovoltaic circuit properties, Applications, and systems. Wind Power: Overview about wind power, Turbine types and terms, Linear momentum and basic theory, Dynamic matching, Blade element theory, Electricity generation. Energy Storage System: Importance of energy storage, Chemical storage, Heat storage, Batteries, Fuel cells, Ultracapacitors, and Mechanical storage.

Course Outcomes

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

CO1: Understand the distributed generation technology.

CO2: Become familiar with modern power system, solar photovoltaic system, wind power system, and energy storage system.

CO3: Realize the technology, design methodologies and operation of distributed generation technology.

Text Books

1. N. Jenkins, J.B. Ekanayake and G. Strbac, “Distributed Generation,” IET.
2. J. Twidell and T. Weir, “Renewable Energy Resources,” Taylor & Francis.

Reference Books

1. A. Khaligh and O. C. Oner, “Energy Harvesting – Solar, Wind, and Ocean Energy Conversion Systems,” CRC Press.
2. C. S. Solanki, “Solar Photovoltaics: Fundamentals, Technologies, and Applications,” PHI.

Course Name: **Optimization Techniques and Applications**
Course Code: **EE-704**
Course Type: **Institute Elective**

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 students to understand the factors that cause the different optimization methods to provide different solutions for the same mathematical problem.

Course Content

Introduction: Historical Development; Engineering applications of Optimization; Design Vector, Design Constraints, Constraint Surface, Objective Function, Objective function Surfaces. Linear Programming: Standard form of linear programming (LP) problem; Canonical form of LP problem; Assumptions in LP Models; 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. Classical Optimization: Stationary points, saddle points; Convexity and concavity of functions; multiple variables optimization, necessary and sufficient conditions, concept of hessian matrix, Newton Raphson method, optimization subject to equality constraints, optimization subject to inequality constraints; Kraush-Kuhn-Tucker Conditions, examples. Non-Linear Programming: Unconstrained algorithms, Direct search method, gradient method, constrained algorithms, separable programming, quadratic programming, augmented LaGrange multiplier method. Kuhn Tucker conditions, examples. Metaheuristic Algorithms: Introduction to Tabu search algorithm, simulated annealing algorithm, genetic algorithm. 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; curse of dimensionality, application.

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.
CO5: Identify the pre-requisite measures required to carry out state space design of the system.

Text Books

1. S. S. Rao, “Engineering Optimization: Theory and Practice,” New Age International (P) Ltd., New Delhi, 2000.

Reference Books

1. S. Chandera, Jaydeva, and A. Mehta, “Numerical Optimization with Applications,” Narosa.
2. H. A. Taha, “Operations Research an Introduction,” Publisher: Pearson.

Course Name: **Electrical Vehicle Technologies**
Course Code: **EE-705**
Course Type: **Institute Elective**

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

Course Objectives

- To impart knowledge about the recent electric vehicle technologies.
- To introduce the fundamental concepts of electric energy source and storage device, battery management system, traction machines, power electronic essentials, and regulations and standards.
- To enable the students to understand how the electric energy system, traction machines, various power electronic essentials, and various regulations and standards works in electric vehicle.

Course Content

Fundamentals of Electric Vehicles: Overview of electric vehicle, Layout of an electric vehicle, History of electric vehicle, Challenges of electric vehicle, Types of electric vehicle. Review of Power Electronics Devices: V-I characteristics and comparison study of different Power electronic devices, Basics, output waveforms, working of different converters used in EVs. Energy Storage Device: Types of energy source, Classification of energy storage technologies, electric batteries, Fuel-cell, Ultracapacitors, Selection of electric battery, and Modelling based on equivalent electric circuits. Charging Infrastructure and Battery Management System: Battery Chargers: Forward/Flyback Converters, Half-Bridge DC–DC Converter, Full-Bridge DC–DC Converter, Power Factor Correction Stage, Bidirectional Battery Chargers, Other Charger Topologies, Inductive Charging, Wireless Charging, Buck Converter and Rectifiers used in EVs, non-isolated and isolated Bidirectional DC–DC Converter. Traction Systems: Structure, principle, and characteristics of DC machine, induction machine, permanent magnet brushless machine, and switched reluctance machine used in electric vehicle. Regulations and Standards: Electric batteries standards, Grid interface standards, and Charging infrastructure standards.

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Understand the power electronic devices, electric energy devices.
CO2: Realize the technology, design methodologies and control strategy of electric vehicles.
CO3: Apply energy management techniques for electric vehicles.
CO4: To apply the knowledge in the charging infrastructure, traction system.

Text Books

1. S. Singh, S. Gairola, and S. Dwivedi, “Electric Vehicle Components and Charging Technologies: Design, Modeling, Simulation and Control, IET.
2. M. Ehsani, Y. Gao, S. E. Gay, and A. Emadi, “Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design, CRC Press.

Reference Books

1. K. T. Chau, “Electric Vehicle Machines and Drives - Design, Analysis and Application,” Wiley.
2. S. Leitman, and B. Brant, “Build Your Own Electric Vehicle,” McGraw Hills.

Course Name: **Elements of Control Engineering** Course Code: **EE-706** Course Type: **Institute Elective**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To study and analyze the various control system components.
- To understand the basic control design methods to meet out desired performance/ specifications.
- To explain the parameters to be taken into consideration while designing a compensator.
- To study the state space modelling and optimal design using state space approach.

Course Content

Introduction: Review of open loop and close loop systems, degenerative and regenerative feedback, transfer function-based models of different systems, study of control system components, sensors and actuators, servo control systems. Control System Analysis: Time domain and frequency domain specifications, concept of stability, asymptotic stability, BIBO stability, Routh-Hurwitz's stability criterion for transfer function models, Nyquist Stability criterion- Stability using Root Locus and Bode plots, absolute stability and relative stability, stability margins. Design of Controllers: Various control schemes, on-off controllers, regulator, tracking control, classical methods for design of control systems, design of compensators-lead, lag, lead lag design using Bode plots, Proportional Integral, and Derivative control strategies and use of their combinations, design of PID Controllers, PID Tuning methods in process control, control of systems with time delay or dead time, feed forward and feedback controllers. State Space Models and Design: State Space models for continuous time linear, single input single output systems, concept of state and state space, linear systems in state space, state models from transfer functions, introduction to multi input multi output systems, transfer function from state space models, controllable and uncontrollable modes, testing for controllability and observability, pole placement design for state feedback systems, Ackerman formula, introduction to observers, full order and reduced order observers.

Course Outcomes

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

CO1: Identify different physical systems and classify them as open loop and close loop control systems.

CO2: Apply different time domain and frequency domain tools to analyze the absolute and relative stability of LTI systems.

CO3: Assess the performance of LTI systems to different inputs and to design basic controllers to meet out desired performance.

CO4: Identify the pre-requisite measures required to carry out state space design of the system.

Text Books

1. G. F. Franklin, J. D. Powell, and A. E. Nacini, "Feedback Control of Dynamic Systems," 4th Ed, Pearson Education Asia, 2002.
2. M. Gopal, L. J. Nagrath, "Control Systems Engineering," Wiley Eastern, 1978.
3. D. R. Choudhary, "Modern Control Engineering," Prentice Hall India, 2005.
4. R. C. Dorf and R. H. Bishop, "Modern Contral Systems," 8^{th} Ed., Addison Wesley, 1998.

Reference Books

1. B. C. Kuo, "Automatic Control Systems," 7th Ed, Prentice Hall India, 1995.

2. E. U. Eronini, “System Dynamics and Control,” Thomson Brooks/Cole, 1999.
3. N. S. Nise, “Control Systems Engineering,” 4 Ed., John Wiley, 2004.
4. G. C. Goodwin, S. F. Graebe, and M. E. Salgado, “Control System Design, Prentice Hall India, 2003.