Master of Technology

In

Electrical Engineering
(Power System)

Course Structure & Syllabus

Department of Electrical Engineering

National Institute of Technology Hamirpur

Hamirpur (HP) - 177005, India

Department of Electrical Engineering
Course Structure of M. Tech (Power System)

SEMESTER-I

Sr. No.	Course No.	Course Name	Teaching Schedule			Hours/Week	Credit
			L	T	P		
1	EE-611	Power System Analysis and Design	4	0	0	4	4
2	EE-612	Power Quality Assessment and Mitigation	4	0	0	4	4
3	EE-613	Advanced Relaying and Protection	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-614	Power System Lab	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-621	Power Generation Operation and Control	4	0	0	4	4
2	EE-622	Power System Restructuring and Deregulation	4	0	0	4	4
3	EE-623	FACTS Devices & Power Transmission	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-624	Power System Design & Analysis Lab	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 (Power System)**
EE-741	Power System Dynamics and Stability
EE-742	Hydro Power Station Practice
EE-743	Power Signal Processing
EE-744	SCADA Systems and Applications
EE-745	Distribution System Planning and Automation
EE-746	Smart Grid Technologies

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

Semester-I

Course Name: **Power System Analysis and Design**
Course Code: **EE-611**
Course Type: **Core**

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

Course Objectives

- To develop a detailed understanding of the range of analysis tools applied to the operation, design, and investigation of modern electric power systems.
- To Model and predict the operation of power system components, including three phase fault studies, stability studies and power system security.
- To enable the students to understand the load flow techniques and monitoring of power system that cause the smooth and reliable operation of complex power system.

Course Content

Network Modelling: System graph, loop, cutest and incidence matrices, Y-bus formation, sparsity, and optimal ordering. Power Flow Analysis: Newton-Raphson method, decoupled and fast decoupled method, formulation of three phase load flow, dc load flow, formulation of AC-DC load flow, sequential solution technique. Fault Studies: Analysis of three phase symmetrical and unsymmetrical faults in phase and sequence domain, phase shift in sequence quantities due to transformer, open circuit faults. Stability Studies: Transient stability analysis, swing equation, stability of multimachine system using modified Euler method and Runge-Kutta method. Power System Security: Factors affecting security, State transition diagram, contingency analysis using network sensitivity method and AC power flow method. State Estimation: Introduction, power system monitoring, energy management system (EMS), function of state estimator, maximum likelihood estimation, static state estimation of power systems – injection only and line only algorithms, treatment of bad data - detection, identification, and suppression of bad data.

Course Outcomes

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

CO1: Develop model of power system components suitable for various power system studies.
CO2: Carry out studies required for the modern power system operation during normal/abnormal condition.
CO3: Simulate and analyze contingencies required to ensure power system security.
CO4: Understand the hierarchy of power system control.
CO5: Understand the techniques involved in the condition monitoring of power systems.

Text Books

1. D. P. Kothari and I. J. Nagrath, “Modern Power System Analysis,” Tata McGraw Hill, New Delhi.
2. Hadi Saadat, “Power System Analysis,” Tata McGraw Hill, New Delhi.
3. G. L. Kusic, “Computer Aided Power System Analysis,” Prentice Hall of India (P), New Delhi.
4. J. Arrilaga, C. P. Arnold, and B. J. Harker, “Computer Modelling of Electric Power System,” John Wiley & Sons.

Reference Books

1. D. P. Kothari, S. I. Ahson, “Computer Aided Power System Analysis & Control,” TMH, New Delhi.
2. G. T. Heydt, “Computer Analysis Methods for Power Systems,” Macmillan, New York.
3. L. P. Singh, “Advanced Power System Analysis and Dynamics,” New Age, New Delhi.
4. N. G. Hingorani and L. Gyugyi, “Understanding FACTS Concepts and Technology of Flexible AC Transmission System.”
5. A. J. Wood, B. Wollenberg, and G. B. Sheble, “Power Generation, Operation and Control,” John Willey
6. A. K. Mahalanabis, D. P. Kothari, and S. I. Ahson, “Computer Aided Power System Analysis & Control, Tata Mc Graw Hill, New Delhi.

Course Name: **Power Quality Assessment and Mitigation**
Course Code: **EE- 612**
Course Type: **Core**

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

Course Objectives

- Understand various power quality issues, and standards
- Voltage sag and interruptions
- Understand Computer tools for harmonic analysis
- Understand Concept of Power Quality Assessment and Mitigation

Course Content

Introduction: Importance of power quality, terms, and definitions of power quality as per IEEE std. 1159 such as transients, short and long duration voltage variations, interruptions, short and long voltage fluctuations, imbalance, flickers, and transients. Symptoms of poor power quality. Definitions and terminology of grounding. Purpose of groundings. Good grounding practices and problems due to poor grounding. Flickers & Transient Voltage: RMS voltage variations in power system and voltage regulation per unit system, complex power. Principles of voltage regulation. Basic power flow and voltage drop. Various devices used for voltage regulation and impact of reactive power management. Various causes of voltage flicker and their effects. Short term and long-term flickers. Various means to reduce flickers. Transient over voltages, sources, impulsive transients, switching transients, Effect of surge impedance and line termination, control of transient voltages. Voltage Sag and Interruptions: Definitions of voltage sag and interruptions. Voltage sags versus interruptions. Economic impact of voltage sag. Major causes and consequences of voltage sags. Voltage sag characteristics. Voltage sag assessment. Influence of fault location and fault level on voltage sag. Areas of vulnerability. Assessment of equipment sensitivity to voltage sags. Voltage sag requirements for computer equipment, CBEMA, ITIC, SEMI F 42 curves. Representation of the results of voltage sags analysis. Voltage sag indices. Mitigation measures for voltage sags, such as UPS, DVR, SMEs, CVT etc., utility solutions and end user solutions. Power Quality Assessment and Mitigation: Power Quality assessment, Power quality indices and standards for assessment disturbances, waveform distortion, voltage and current unbalances. Power assessment under waveform distortion conditions. Power quality state estimation, State variable model, observability analysis, capabilities of harmonic state estimation. Test systems. Mitigation techniques at different environments. Power Quality Monitoring: Need of power quality monitoring and approaches followed in power quality monitoring. Power quality monitoring objectives and requirements. Initial site survey. Power quality Instrumentation. Selection of power quality monitors, selection of monitoring location and period. System wide and discrete power quality monitoring. Setting thresholds on monitors, d data collection and analysis. Selection of transducers. Harmonic monitoring, transient monitoring, event recording and flicker monitoring. Power Quality Assessment and Mitigation: Power Quality assessment, Power quality indices and standards for assessment disturbances, waveform distortion, voltage, and current unbalances. Power assessment under waveform distortion conditions. Power quality state estimation, State variable model, observability analysis, capabilities of harmonic state estimation. Test systems. Mitigation techniques at different environments.

Course Outcomes

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

CO1: Understand various power quality issues, and standards and the associated problems related to power quality.
CO2: To make the students aware about Voltage sag, swell, filter, variations, and interruptions
CO3: Understand Computer tools for harmonic analysis
CO4: Understand Concept of Power Quality Assessment and Mitigation

CO5: The tools and modern techniques used to improve the power quality

Text Books:

1. G. T. Heydt, “Electric Power Quality,” McGraw-Hill Professional, 2007.
2. M. H. J. Bollen, “Understanding Power Quality Problems,” IEEE Press, 2000.
3. J. Arrillaga, “Power System Quality Assessment,” John Wiley, 2000.

Reference Books:

1. E. Fuchs, M. A. S. Masoum, “Power Quality in Power Systems and Electrical Machines, Elsevier Inc.,2008.
2. A. Moreno, “Power Quality-Mitigation Technologies in a Disturbed Environment,” Springer, 2007.
3. Mahesh Kumar Mishra, “Power Quality in Power Distribution Systems: Concepts and Applications,” CRC Press.

Course Name: **Advanced Relaying and Protection**
Course Code: **EE-613**
Course Type: **Core**

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

Course Objectives

- To learn about various specifications and design of power system protection
- To have knowledge about various power apparatus and protection schemes.
- To impart knowledge about latest state of art in protection area.

Course Content

Introduction to Protective Relaying: Relay terminology, Definitions, Classification, electromechanical, static, and digital numerical relays. Design-factors affecting performance of a protection scheme; faults-types and evaluation, Instrument transformers for protection. Relay Schematics and Analysis: Over Current Relay, Instantaneous/Inverse Time –IDMT Characteristics; Directional Relays; Differential Relays- Restraining Characteristics; Distance Relays: Types- Characteristics. Protection of Power System Equipment and System Grounding: Generator, Transformer, Transmission Systems, Busbars, Motors, Pilot wire and Carrier Current Protection Schemes, Ground faults and protection; Load shedding and Frequency relaying, out of step relaying, Re-closing, and synchronizing. Digital Protection and Relay Testing: Basic elements of digital protection, Digital signal processing, Digital filtering in protection relay, digital data transmission, Numeric relay hardware, relay algorithm, distance relays, direction comparison relays, differential relays, software considerations, numeric relay testing, concept of modern coordinated control system.

Course Outcomes

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

CO1: Understand basic protection schemes and protection of power equipment.
CO2: Understand the mandatory specifications of power apparatus and relay testing.
CO3: Apply principles and algorithms of digital protection schemes and modern coordinated control and protection of power system.

Text Sooks

1. A. T. John and A. K. Salman, “Digital Protection for Power Systems,” IEEE Power Series-15, Peter Peregrines Ltd, UK.
2. C. R. Mason, “The Art & Science of Protective Relaying,” John Wiley & Sons.
3. T. S. M. Rao, “Power System Protection: Static Relays with Microprocessor Applications,” Tata McGraw Hill.
4. L. P. Singh, “Digital Protection, Protective Relaying from Electromechanical to Microprocessor,” John Wiley & Sons.

Reference Books

1. J. L. Blackburn, “Protective Relaying, Principles and Applications,” Dekker.
2. A. R. Warrington, “Protective Relays,” Vol. 1 & 2, Chapman and Hall.
3. Stanely H. Horowitz, Arun G. Phadke and Charles F. Henville, “Power System Relaying,” Wiely-Blackwell Publications.
4. J. Lewis Blackburn and Thomas J. Domin, “Protective Relaying: Principles and Applications,” CRC Press

Course Name: **Power System Lab**
Course Code: **EE-614**

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

Course Objectives

- To provide power system-based problem-oriented knowledge, analyzing them in MATLAB framework
- To address the concepts & approaches behind analysis of complex power system network using MATLAB
- To formulate solutions of problems and implemented their algorithm in MATLAB

List of Experiments

1. Formation of incidence matrices and bus admittance matrix of a power network using MATLAB
2. Power flow analysis of standard test systems using Power world Simulator/MATLAB packages
3. Short-circuit analysis of standard test systems using Power world Simulator/MATLAB packages
4. Transient stability analysis of standard test systems using Power world Simulator /MATLAB packages
5. Analysis of R, RL, RC, and RLC circuits using MATLAB/SIMULINK
6. Simulation of Capacitor switching transient using SIMULINK
7. Modelling of a simple Spring-Mass-Damper system and study of the impulse, unit step and ramp responses
8. Stability analysis of the above system using Root locus and Bode plots
9. SIMULINK modelling and analysis of automatic load frequency control of multi- area power systems.
10. Implementation of Lambda-iteration technique using MATLAB
11. Lambda-iteration technique for Economic load dispatch with/without losses for a standard test system using MATLAB
12. Implementation of AC-DC load flow using MATLAB

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: Understand the power system problem and find the solution of the same.

CO2: Identify and achieve the programming task involved in a given problem such as OPF, economic load dispatch etc.

CO3: Analyse various power system problems and find their solution using MATLAB.

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

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

Course Objectives

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

Course Content

Artificial Intelligence: Definition, problem solving methods, searching techniques, knowledge representation, reasoning methods, predicate logic, predicate calculus, multi-value logic. Fuzzy Logic: Concepts, fuzzy relations, membership functions, matrix representation, de-fuzzification methods. 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, constraint satisfaction problem and example.

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

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

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

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," Addition 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, example.

Course Outcomes

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

CO1: Identify different types of optimization techniques and problems.

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

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

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

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

Course Content

Introduction: Basic concepts and definitions, artificial intelligence, genetic algorithms (GAs), evolutionary programming (EP). Genetic algorithm: Coding, fitness function, Calculation of the number of bit required for a variable, GAs operators, crossover and mutation, roulette wheel method for selection process, cumulative probabilities, Basic flow chart, GAs for optimization detail steps, Similarities between GAs and traditional methods, Differences between GAs and traditional methods. Evolutionary programming: Initialization, Creation of offspring, Competition and selection, Gaussian random numbers, standard deviation, Difference between GAs and EP, basic algorithm, step by step procedure of evolutionary programming for optimization. Applications: Gas 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 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. 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, 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 VI 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 its applications, performance parameters, evaluation of 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 its applications, performance parameters, analyze 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 degrees 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: Able to decide about choice of power electronic switching devices implementing practical circuits
CO2: Able to 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: Analyse 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 drives and its control.
- To introduce the fundamental concepts relevant to induction motor synchronous motor drives and their various control methods.
- To enable the students to understand the concepts of fractional horse power drives and its applications.

Course Content

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

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

Course Content

Understanding, analysis and application of electrical energy management-measurement and accounting techniques-consumption patterns- conservation methods-application in industrial cases. System approach and End use approach to efficient use of electricity. Electricity tariff types; Energy auditing: Types and objectives-audit instruments-ECO assessment and Economic methods-specific energy analysis-Minimum energy paths- consumption models-Case study. Electric motors-Energy efficient controls and starting efficiency- Motor Efficiency and Load Analysis- Energy efficient / 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. Lighting- Energy efficient light sources-Energy conservation in Lighting Schemes- Electronic Ballast-Power quality issues-Luminaries, case study. Cogeneration- Types and Schemes-Optimal operation of cogeneration plants-case study. Electric loads of Air conditioning & Refrigeration- Energy conservation measures- Cool storage. Types-Optimal operation-case study; Electric water heating- Geysers-Solar Water Heaters- Power Consumption in Compressors, Energy conservation measures; Electrolytic Process; Computer Controls-software-EMS.

Course Outcomes

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

CO1: Obtain the knowledge about energy conservation act, policy, regulations, and business practices.
CO2: Analyze different energy systems from a supply and demand perspective.
CO3: Recognize opportunities for rational use of energy in industrial application.
CO4: Apply knowledge of Energy Conservation Opportunities in a range of contexts.
CO5: Identify and develop innovative energy efficiency solutions and demand management strategies for future.

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

Course Content

Modern Power System: Generation, Transmission, Distribution, Loads, Introduction to distributed generation (DG), Technologies of DG, IEEE-1547. 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 DGs Units in Power Systems, Integration of DGs units in distribution network. Modern Power Electronics for DGs Applications: Multiple and single input dc-dc converters, ac-dc and dc-ac converters, technical restrictions, Protection of DGs, Economics of DGs, Pricing and financing framework for DG units, Optimal placement of DGs, Case studies. Introduction to Microgrids: AC and DC microgrids, Operational framework of Microgrids, Anti-islanding schemes, Distribution management system, 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 application in distribution system
CO2: Design and develop modern systems for the upkeep of pollution free environment
CO3: Utilize tools for modelling, analysing, 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.

Semester-II

Course Name: **Power Generation Operation and Control**
Course Code: E**E-621**
Course Type: **Core**

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

Course Objectives

- To impart knowledge about the optimization and control of power generation and transmission industry.
- To introduce the fundamental concepts relevant to input-output generator characteristics, economic dispatch, unit commitment, hydro thermal scheduling, generation control and optimal power flow
- To enable the students to understand the factors that cause the optimal operation as well as control of power system possible

Course Content

Introduction: Characteristics of power generation units (thermal, nuclear, hydro, pumped hydro), variation in thermal unit characteristics with multiple valves, Economic dispatch without line losses, lambda iteration method, gradient method, Newton's method, Economic dispatch with line losses, base point, and participation factors. Transmission losses, co-ordination equations, incremental losses, penalty factors, B matrix loss formula (without derivation), methods of calculating penalty factors. Unit Commitment: Constraints in unit commitment, spinning reserve, thermal unit constraints, other constraints, methods of solving Unit commitment problem, priority list method, Dynamic programming method and Lagrange relaxation methods, examples. Generation with Limited Energy Supply: Take or Pay fuel supply contract, composite generation production cost function, solution by gradient search techniques. Hydrothermal Co-ordination: Introduction to long range and short-range hydro scheduling problem, types of scheduling problems, scheduling energy, short-term hydrothermal scheduling, lambda-gamma iteration method, gradient method, gradient approach for short term hydro scheduling, cascaded hydro plants scheduling, pumped storage hydro scheduling. Optimal Power Flow: Introduction to optimal power flow (OPF), solution of OPF using gradient method, newton method, linear sensitivity analysis, sensitivity coefficients of an AC network model, linear programming method for OPF with only real power variables, linear programming with AC power variables and detailed cost functions. Control of Generation: Introduction, Generator model, load model, prime-mover model, governor model, tie-line model, generation control, supplementary control action, tie-line control, generation allocation, automatic generation control(AGC) implementation, AGC feature.

Course Outcomes

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

CO1: Identify different power generation, operation, and control problems

CO2: Describe problems like economic dispatch, unit commitment, hydro thermal scheduling, optimal power flow, generation control

CO3: Apply principles and algorithms of optimization to solve problems described in CO2

CO4: Assess the results obtained by solving above problems

Text Books

1. A. J. Wood and B. F. Wollenberg, "Power Generation Operation and Control," John Wiley.

Reference Books

1. O. I. Elgerd, "Electrical Energy System Theory," TMH Edison, New Delhi.
2. N. V. Ramana, "Power System Operation and Control," Pearson.

Course Name: **Power System Restructuring and Deregulation**
Course Code: **EE-622**
Course Type: **Core**

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

Course Objectives

- To impart knowledge about the restructuring and deregulation of power sector.
- To introduce the fundamental concepts relevant to OASIS, congestion management etc.
- To enable the students to understand the factors related with deregulation of power industry in different countries.

Course Content

Introduction: Basic concept and definitions, privatization, restructuring, transmission open access, wheeling, deregulation, components of deregulated system, advantages of competitive system. Power System Restructuring: An overview of the restructured power system, Difference between integrated power system and restructured power system. Explanation with suitable practical examples. Deregulation of Power Sector: Separation of ownership and operation, Deregulated models, pool model, pool and bilateral trades model, Multilateral trade model. Independent System Operator activities in pool market, Wholesale electricity market characteristics, central auction, single auction power pool, double auction power pool, market clearing and pricing, Market Power and its Mitigation Techniques, Bilateral trading, Ancillary services, Transmission Pricing. Open Access Same Time Information System (OASIS): Introduction, structure, functionality, implementation, posting of information, uses. Congestion Management: Congestion management in normal operation, explanation with suitable example, total transfer capability (TTC), Available transfer capability (ATC), Transmission Reliability Margin (TRM), Capacity Benefit Margin (CBM), Existing Transmission Commitments (ETC). Introduction to Electrical Power System Resilience. Different Experiences in Deregulation: U.S.A, Canada, U.K, Japan, Switzerland, Australia, Sweden, Germany, and Indian power system.

Course Outcomes

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

CO1: Identify various concepts of restructuring and deregulation of power sector.
CO2: Describe important concepts related with deregulation like market power, OASIS, congestion management etc.
CO3: Apply principal to explain various problems related with deregulation of power sector.
CO4: Assess the results obtained by solving above problems.

Text Books

1. M. Shahidehpour and M. Alomoush, “Restructured Electrical Power Systems,” Marcel Dekker, New York.
2. P. Deo and S. Modak, “Electricity Reforms & Green Power Development,” World Institute of Sustainable Energy, 2005.
3. A. J. Wood and B. F. Wollenberg, “Power Generation Operation and Control,” John Wiley & Sons, 2006.

References Books

1. L. L. Lai, “Power System Restructuring and Deregulation,” John Wiley & Sons Ltd.
2. R. C. Bansal, M. Mishra, and Y. R. Sood, “Electric Power Systems Resiliency: Modelling, Opportunity and Challenges,” Elsevier Inc. Imprint Academic Press, 2022.
3. L. Philipson and H. L. Willis, “Understanding Electric Utilities and Deregulation,” Marcel Dekker, New York.
4. M. llic, F. Galiana, and L. Fink, “Power System Restructuring Engineering & Economics” Kulwer Academic Publisher, USA.

Course Name: **FACTS Devices and Power Transmission**
Course Code: **EE- 623**
Course Type: **Core**

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

Course Objectives

- To provide basic knowledge of the various structures of the compensators and its techniques in FACTS.
- To provide basic understanding of active and reactive power flow in the transmission line with and without compensations
- To enable students to understand the various order of harmonics in VSIs when used in FACTS
- To learn the different configurations of shunt, series, and combined compensators to maximize the power flow

Course Content

Basic of FACTS Controllers: Need of Transmission interconnection, FACTS role in transmission line, flow of power in AC system, brief description and definitions of FACTS controllers, comparisons between FACTS and HVDC systems. Power Electronics Devices in FACTS: Prospective of power devices in FACTS, Characteristics of Power Devices, Basics of Voltage source inverter, Harmonic analysis of different inverters, PWM controlled VSIs when used in FACTS. AC Transmission Line and Compensation: AC Transmission Line analysis of uncompensated line: transmission line equations, performance of a line connected to unity power factor load, performance of a symmetrical line, passive reactive power compensation: compensation by a series capacitor connected at the mid-point of the line, shunt capacitor compensation connected at the midpoint of the line, comparison between series and shunt capacitor compensation, Compensation with SSSC and STATCOM with examples. Static Shunt Compensators: Objectives of shunt compensation: midpoint voltage regulation for line segmentation, methods of controllable VAR generation: variable impedance type static VAR generators: TSC and TCR, FC-TCR and its control voltage source converter type VAR generators: Static Synchronous Compensator (STATCOM). Static Series Compensators: Objectives of series compensation: voltage stability, variable impedance type series compensators: Thyristor-Controlled Series Capacitor (TCSC), GTO Thyristor-Controlled Series Capacitor (GCSC), Control techniques involved in TCSC and GCSC, voltage source converter type series compensators: Static Synchronous Series Compensator (SSSC), Indirect and direct control schemes of STATCOM. Phase Shifters and Combined Shunt/Series Compensators: Basic operating principles, configurations, and characteristics: Phase shifter, Unified Power Flow Controllers (UPFC), Interline Power Flow Controller (IPFC), comparison of UPFC with the other configurations.

Course Outcomes

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

CO1: Examine the interconnection system of the transmission line with their limitations
CO2: Analyze the effect of series and shunt passive compensators
CO3: Carry out performance evaluation of different static, shunt, and series compensators
CO4: Carry out evaluation of different configurations of combined compensators

Text Books

1. N. Hingorani and L. Gyigyi, “Understanding FACTS,” IEEE Press.
2. K. R. Padiyar, “FACTS Controllers in Power Transmission and Distribution,” New Age.

Reference Books

1. R. M. Mathur and R. K. Varma, “Thyristor-based FACTS Controllers for Electrical Transmission Systems,” Willey.

Course Name: **Power System Design & Analysis Lab** Course Code: **EE-624**	
Contact Hours/Week: **4P**	Course Credits: **02**

Course Objectives

- To enable students to design a system/ process to meet desired needs with in realistic constraints.
- To provide skills for developing Simulink model of practical problems and analyzing their results in MATLAB.
- To enable the students to demonstrate a mastery in power system design using MATLAB.

List of Experiments

1. Simulation of power quality problems (like Sag/Swell, interruption, transients, harmonics, flickers etc.) using SIMULINK.
2. Generating FFT for the above said power quality problems using MATLAB/SIMULINK.
3. Simulation and response analysis of excitation system for impulse, unit step, and ramp inputs using SIMULINK.
4. Simulation and analysis of governor system for impulse, unit step, and ramp inputs using SIMULINK.
5. SIMULINK modelling of standard test system with generator excitation and governor action.
6. Small signal stability analysis of standard test systems in MATLAB.
7. Development of any five classical optimization techniques.
8. SIMULINK modelling of power electronic 3 phase, 6 pulse converters using PWM technique.
9. SIMULINK modelling of power electronic 3 phase, chopper using any commutation technique.
10. SIMULINK modelling of power electronic 3 phase, cycloconverter.
11. Implementation of forward dynamic programming for unit commitment problem.
12. Design of passive and active filters using SIMULINK.

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: Work on Power system problems and model them in MATLAB.

CO2: Analyse, simulate, and design 3-phase converter, cycloconverter and chopper using MATLAB/Simulink.

CO3: Carry out design and implementation of power system, modelling, and filter design.

Course Name: **Power System Dynamics and Stability**
Course Code: **EE-741**
Course Type: **Programme Elective-III**

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

Course Objectives

- To develop dynamic modeling of a synchronous machine.
- To describe the modeling of excitation and speed governing system.
- To analyze the small signal stability without and with controllers.
- To explain the methods to enhance the small signal stability of the power system

Course Content

Introduction Basic Concepts, Definitions and Classification of Power System Stability/ Synchronous machine modeling for stability studies: Basic equations of a synchronous machine, the dq0 transformation, per unit representation, equivalent circuits for direct and quadrature axes, steady state analysis, transient performance, magnetic saturation, equations of motion, swing equation, simplified model with ammortisseurs neglected, constant flux linkage model. Excitation and Prime Mover Controllers: Elements of excitation systems, types of excitation system, DC, AC and static excitation systems, system representation by block diagram and state equations, prime mover control system. Small Signal Stability of Power Systems: Fundamental concepts of stability of dynamic systems, Eigen properties of the state matrix, small signal stability of a single machine infinite bus system, effects of excitation system, power system stabilizers, system state matrix with amortisseurs, small signal stability of multi machine systems. Use of PSS to improve small signal stability. Transient stability: Equal area criterion, numerical integration methods, simulation of power system dynamic response, direct methods of transient stability analysis – description of transient energy function approach, limitations of the direct methods. Methods of improving transient stability. Voltage Stability: Basic concepts related to voltage stability, voltage collapse, voltage stability analysis – static and dynamic analysis, the continuation power flow analysis, prevention of voltage collapse.

Course Outcomes

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

CO1: Perform fundamental computation and modeling of power system control and stability.
CO2: Develop skills to model control devices that can be incorporated in power system simulations.
CO3: Analyse dynamic behavior of power control systems subject to various disturbances from the aggregated behavior of the many dynamic devices.

Text Books:

1. P. Kundur, “Power System Stability and Control,” Mc Graw Hill.
2. R. Ramanujam, “Power System Dynamics: Analysis and Simulation,” PHI Learning.

Reference Books

1. K. R. Padiyar, “Power System Dynamics,” B S Publications.
2. P. M. Anderson and A. A. Fouad, “Power System Control and Stability,” *IEEE* Press.

Course Name: **Hydro Power Station Practice**
Course Code: **EE-742**
Course Type: **Programme Elective-III**

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

Course Objectives

- To impart knowledge about the planning of hydro power plant, various equipment's used and governing of turbines.
- To introduce the fundamental concepts relevant to turbines and generators, frequency control and AVR and voltage control.
- To enable the students to understand the main design factors of HPP and efficient operation of hydro plants.

Course Content

Layout and Planning of Hydro Power Plant: Introduction, layout of power house, types of hydro power schemes, stages of investigation, PFR, DPR, hydrology, water availability and water conductor system. Layout of electrical equipment's in hydro power station. Governing and Testing of Water Turbines: Governing of turbines: Mechanical governors, electro hydraulic governors, supply of pressure coils, and speed and pressure regulation of turbine governor, relief valves, frequency control, economic consideration, time constants of governors. Testing of Water Turbines: Efficiency, power tests at manufacturers' works, testing at site, efficiency tests and model tests. Hydro Generators: Specification; characteristics, stability, Hydro design, losses, insulation and temperature limits, electrical tests. General Arrangement of Water Wheel Generator: Large horizontal shaft generators, vertical generators, reversible generators, low speed generators, umbrella type, Jacks, generators cooling and ventilation, fire protection. Excitation System & Voltage Regulators: Excitation requirements, sources, drives, automatic excitation, control equipment and requirements, typical testing scheme of equipment's. Special Feature of Stability: Special feature of stability of hydro power plants.

Course Outcomes

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

CO1: Identify different types of hydro power plants, various equipment, and planning stages.
CO2: Describe automatic generation control like turbine governing, AVR, and generator arrangements.
CO3: Apply various testing schemes for power plant equipment including generating transformer for efficient operation of plant.
CO4: Assess the results of hydrological analysis and choice for no. of units and stability.

Text Books

1. J. G. Brown, "Hydro Electric Engineering Practice," Vol. I, II, and III, Blackie.
2. M. V. Deshpande, "Elements of Electrical Power Station Design," Prentice Hall of India.
3. P. S. Nigam, "Handbook of Hydroelectric Engineering," Nem Chand & Bros, Roorkee.

Reference Books

1. B. R. Gupta, "Generation of Electrical Energy," S. Chand & Co.
2. D. P. Kothari and I. J. Nagrath, "Electrical Machines," TMH.
3. P. Kundur, "Power System Stability and Control," Mc-Graw Hill.

Course Name: **Power Signal Processing**
Course Code: **EE-743**
Course Type: **Programme Elective-III**

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

Course Objectives

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

Course Content

Basics of Digital Signal Processing: Sampling, Fourier series and Fourier transform, DFT, phasor measurement techniques, phasor representation, amplitude, phase, and frequency estimation of undistorted single frequency sine wave, two and three sample techniques. Phasor Estimation: Phasor estimation using PLL structure, and Kalman filter, phasor estimation of nominal and off-nominal frequency inputs, recursive and non-recursive updates, phasor estimation with fractional cycle date window. Signal Processing and Power Quality: Power system frequency estimation from Balanced and unbalanced input, PMUs, synchro phasors, removal of dc offset, processing of stationary signals, frequency-domain analysis and signal transformation, estimation of harmonics and inter harmonics. Processing of Non-stationary Signals: Discrete STFT for analyzing time-evolving signal components, Discrete wavelet transforms for time–scale analysis of disturbances grid synchronization techniques for single-phase and three-phase systems based on PLL and Fourier analysis, Hilbert transform, T/4 transport delay, SOGI, MAF.

Course Outcomes

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

CO1: Identify suitable signal processing technique for power signal applications

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

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

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

Text Books

1. B. P. Lathi, “Essentials of Digital Signal Processing,” Cambridge University Press.
2. A. G. Phadke and J. S. Thorp, “Synchronized Phasor Measurements and Their Applications,” Springer.
3. M. H. J. Bollen, “Signal Processing of Power Quality Disturbances,” Irene Y. H. Gu, IEEE Press.

Reference Books

1. K. Sozański, “Digital Signal Processing in Power Electronics Control Circuits,” Springer.
2. S. R. Bide, “Digital Power System Protection,” PHI.
3. R. Teodorescu, M. Liserre, and P. Rodr´ıguez, “Grid Converters for Photovoltaic and Wind Power Systems,” IEEE-Wiley.

Course Name: **SCADA Systems and Applications**
Course Code: **EE-744**
Course Type: **Programme Elective-III**

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

Course Objectives

- To introduce computers and communication in electrical power engineering, focusing on their relationship with Supervisory Control and Data Acquisition (SCADA).
- To introduce power system automation and recent technological advancements in computer, communication, networking, and power system security.
- To provide knowledge on power system components and industrial communication technologies.

Course Content

Introduction to SCADA: Data acquisition systems, evolution of SCADA, communication technologies, monitoring and supervisory functions, SCADA applications in utility automation, industries. SCADA Components and Architecture: Remote Terminal Unit (RTU), Intelligent Electronic Devices (IED), Programmable Logic Controller (PLC), SCADA server, SCADA/HMI systems. Various SCADA architectures - advantages and disadvantages of each system - single unified standard architecture - IEC 61850. SCADA Communication: Various industrial communication technologies -wired and wireless methods and fiber optics, open standard communication protocols. SCADA Applications: Utility applications - transmission and distribution sector - operations, monitoring, analysis, and improvement. industrial applications - oil, gas, and water. Case studies, implementation, and simulation exercises.

Course Outcomes

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

CO1: Understand energy conservation and international standards in monitoring energy consumption.
CO2: Learn computer methods for power system applications and monitoring.
CO3: Grasp operator interfaces and economic benefits of SCADA systems.'
CO4: Differentiate between soft and hard HMIs and understand RTU functions.

Text Books

4. S. A. Boyer, "SCADA: Supervisory Control and Data Acquisition," Instrument Society of America Publications, USA.

Reference Books

4. G. Clarke, "Deon Reynders: Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems," Newnes Publications, Oxford, UK.
5. W. T. Shaw, "Cybersecurity for SCADA Systems," PennWell Books.
6. D. Bailey, "Practical SCADA for Industry," Edwin Wright, Newnes.
7. M. Wiebe, "A guide to Utility Automation: AMR, SCADA, and IT Systems for Electric Power," PennWell.

Course Name: **Distribution System Planning and Automation**
Course Code: **EE- 745**
Course Type: **Programme Elective-III**

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

Course Objectives

- To make the students aware about the characteristics of distribution systems and transmission systems
- Students shall Design, analyse, and evaluate distribution systems based on forecasted data
- Design and evaluate a distribution system for a given geographical service area from alternate design alternatives.
- Familiarize with basic architecture of Distribution automation system

Course Content

Power Computational Techniques in Distribution Systems: Complex power concept, per unit system, power loss calculation, voltage regulation techniques, components modeling, power flow methods. Distribution Automation and Control Functions: Demand side management, voltage/var control, fault detection, trouble calls, restoration functions, Reconfiguration, optimization techniques. Distribution System Planning: Planning and forecasting techniques – Present and future – Role of computers- Load Characteristics- Load forecasting using ANN – Load management – tariffs and metering of energy. Distribution System Automation: Reforms in power sector –Intelligent systems in distribution automation, Methods of improvement –Automation – Communication systems – Sensors –Basic architecture of Distribution automation system – software and open architecture – RTU and Data communication – SCADA Requirement and Application: Functions –Communication media for distribution system automation- Communication protocols for Distribution systems – IEC 61850 and IEEE 802.3 standards, Distribution System Management: Integrated sub–station metering system, automatic meter reading, cost benefit analysis.

Course Outcomes

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

CO1: Understand and distinguish characteristics of distribution systems from transmission systems
CO2: Design, analyse and evaluate distribution system design based on forecasted data
CO3: Design and evaluate a distribution system for a given geographical service area from alternate design alternatives.
CO4: Familiarize with basic architecture of Distribution automation system
CO5: Know about Communication protocols for Distribution systems

Text Books:

1. T. Gonen, "Electric Power Distribution Engineering," Mc-Graw Hill, 1986.
2. J. A. Momoh, "Electric Power Distribution, Automation, Protection and Control," CRC press, Taylor and Francis.

Reference Books

1. A. S. PABLA: Electric Power Distribution, TMH, 2000.
2. H. L. Willis, "Distributed Power Generation Planning and Evaluation," CRC Press, 2000.

Course Name: **Smart Grid Technology** Course Code: EE-746 Course Type: **Programme Elective-III**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives • Understand the features of Smart Grid • Assess the role of Smart Grid Communications and Measurement Technology • To introduce the impact of Distribution Generation Technologies in Smart grids • Understand the operation and Power Quality Management in Smart Grid • To introduce the fundamental concepts relevant to Demand side management in Smart Grid.
Introduction to Smart Grid: Need for smart grid, smart grid priority areas, regulatory challenges, Smart grid drivers, functions, opportunities, challenges and benefits, Difference between conventional grid & Smart Grid, Smart grid architecture, standards-policies, Smart-grid activities in India. Monitoring systems: PMU, Smart Meters, and Measurements Technologies, Wide Area Monitoring Systems (WAMS), Phasor Measurement Units (PMU), SCADA systems, Smart Meters, Smart Appliances Advanced Metering Infrastructure (AMI). Communication systems, EV and challenges in the grid, cyber security and block chain technology. Renewable Energy Sources, Demand side management, Potential benefits of Demand side management in smart grid, enabling smart technologies for demand response.
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Describe the need of smart grid systems and its architecture. CO2: Demonstrate the concepts of demand side management in Smart Grid CO3: Understand the usage and Potential benefits of Demand side management.
Textbooks 1. Smart Grids Advanced Technologies and Solutions by Stuart Borlase, CRC Press, 2017. 2. Smart Grid Fundamentals of Design and Analysis by James Momoh, Wiley, 2012. **Reference Books** 1. Renewable and Efficient Electric Power System by Gil Masters, Wiley–IEEE Press, 2004. 2. Wind Power in Power Systems by T. Ackermann, Hoboken, NJ, USA, John Wiley, 2005

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

- Learn modelling, analysis, and operation of power systems.
- Instills a practical knowledge of large-scale power system analysis.
- 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.
3. S. Borlase, “Smart Grids: Infrastructure, Technology, and Solutions,” David J. Hill, CRC Press

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

Course Content

Introduction: Basic concepts and definitions, artificial intelligence, genetic algorithms (GAs), evolutionary programming (EP). 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. 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 applications for economic power dispatch and optimal power flow, applications of EP for economic power dispatches and optimal powers flow.

Course Outcomes

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 the distributed generation technology
- To introduce the modern power system, solar photovoltaic system, wind power system, and energy storage system.
- To enable the 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: 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: familiarise 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 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; 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 analyse 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," 8th 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.