Master of Technology

In

Electrical Engineering (Power System)

Course Structure & Syllabus

Department of Electrical Engineering

National Institute of Technology Hamirpur

Hamirpur (HP) – 177005, India

Course Structure of M. Tech. Department of Electrical Engineering (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 System Quality Assessment	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 Simulation 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 & Control	4	0	0	4	4
2	EE-622	Power Systems 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	Programme Elective-IV	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 & IV: List of Programme Electives is given in the Annexure

SEMESTER-III

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

SEMESTER-IV

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

Total Credit of the Programme = 84

Annexure
List of Programme Electives

Programme Elective I

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

Programme Elective II

EE-721 Power System Dynamics and Stability
EE-722 Hydro Power Station Practice
EE-753 Energy Auditing & Management

Programme Elective III

EE-723 Power Signal Processing
EE-724 Solid State Control of Drives
EE-761 Solid State Devices and Converters

Programme Elective IV

EE-726 Distributed Generation and Microgrid
EE-727 SCADA Systems and Applications
EE-728 Signal Conditioning and Data Acquisition

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 and Power Flow: 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), SCADA, function of state estimator, maximum likelihood estimation.

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.

Books and References

1. Modern Power System Analysis by D. P. Kothari and I. J. Nagrath, Tata McGraw Hill Publishing Co. Ltd., New Delhi.
2. Power System Analysis by Hadi Saadat, Tata McGraw Hill Publishing Co. Ltd., New Delhi.
3. Computer Aided Power System Analysis by George L. Kusic, Prentice Hall of India (P) Ltd., New Delhi.
4. Computer Modelling of Electric Power System by J. Arrilaga, C. P. Arnold, B. J. Harker, John Wiley & Sons. K. Mahailnaos.
5. Computer Aided Power System Analysis & Control by D. P. Kothari, S. I. Ahson, Tata McGraw Hill Publishing Co. Ltd., New Delhi.
6. Computer Analysis Methods for Power Systems by G. T. Heydt, Macmillan Publishing Company, New York.
7. Advanced Power System Analysis and Dynamics by L. P. Singh, New Age, International Publishers, New Delhi.
8. Understanding FACTS Concepts and Technology of Flexible AC Transmission System by N.G. Hingorani and L. Gyugyi.

Course Name: Power System Quality Assessment
Course Code: EE-612
Course Type: Core

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

Course Objectives

- To impart knowledge about the power quality and its assessments.
- To introduce the fundamental concepts of waveform processing techniques, monitoring of power qualities disturbances.
- To enable the students to understand how power quality studies are carried out in a distribution system.
- To enable the students to understand the factors that causes the harmonics and their effect on the power system.
- To enable the student to understand how harmonic students are carried out in a power system.
- To enable the student to understand the design concepts of grounding.

Course Content

Introduction: Power quality-voltage quality-overview of power quality phenomena-classification of power quality issues-power quality measures and standards-THD-TIF-DIN-message weights-flicker factor-transient phenomena-occurrence of power quality problems-power acceptability curves-IEEE guides, EMC standards and recommended practices. Power Assessment Under Waveform Distortion: Introduction, single phase definitions, three phase definitions, illustrative examples. Waveform Processing Techniques: Fundamental frequency characterization, Fourier analysis, Fast Fourier Transform, Window functions, Efficiency of FFT algorithms, alternative transforms, wavelet transform, Hartley transform, Automation of disturbance recognition. Power Quality Monitoring: Introduction, transducers, CT, PT, power quality instrumentation, Harmonic monitoring, event recording, flicker monitoring, assessment of voltage and current unbalance, examples of application. Evaluation of power system harmonic distortion: Introduction, direct harmonic analysis, incorporation of harmonic voltage sources, derivation of network harmonic impedances, solution by direct injection, Representation of individual power system components, implementation of harmonic analysis, post processing and display of results. Harmonic Mitigation: Passive filtering, Harmonic resonance, Impedance Scan Analysis-Active Power Factor Corrected Single Phase Front End, introduction to three Phase APFC and Control Techniques. Grounding: Grounding and wiring–introduction-NEC grounding requirements-reasons for grounding-typical grounding and wiring problems-solutions to grounding and wiring problems.

Course Outcomes

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

CO1: Identify different power quality problems present in residential, commercial and industrial power systems.
CO2: Understand the waveform processing techniques and their applications for power quality assessment.
CO3: Apply basic principles to carry out harmonic load flow studies and the filter design concepts to mitigate harmonics.
CO4: Design a grounding mat for a substation.

Books and References

1. Electric Power Quality by G. T. Heydt, Stars in a Circle Publishers.
2. Understanding Power Quality Problems by Math H. Bollen John Wiley and Sons.
3. Power System Quality Assessment by J. Arrillaga and N. R. Watson John Wiley and Sons
4. Power System Harmonic Analysis by J. Arrillaga, B. C. Smith, N. R. Watson & A. R. Wood John Wiley.
5. Electrical Power System Quality by Surya Santoso, H. Wayne Beaty, Roger C. Dugan, Mark F. McGranaghan McGraw Hills.

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

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

Course Objectives

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

Course Content

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’s: Generator, Transformer, Transmission Systems, Busbars, Motors; Pilot wire and Carrier Current Schemes. System grounding: Ground faults and protection; Load shedding and frequency relaying; Out of step relaying; Re-closing and synchronizing. Integrated and multifunction protection schemes: SCADA based protection systems, Testing of Relays. 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: Identify different power system protection techniques and fault calculations and evaluation.

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

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

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

Books and References

1. Digital protection for power systems by A. T. John and A K Salman- -IEE power series-15, Peter Peregrines Ltd, UK.
2. The art and science of protective relaying by C.R. Mason, John Wiley & Sons.
3. Protective Relays, Vol. 1&2 by A.R. Warrington, Chapman and Hall.
4. Power system protection static relays with microprocessor applications by T S. Madhav Rao, Tata McGraw Hill Publication.
5. Protective Relaying, Principles and Applications by Blackburn, J. Lewis, Marcel Dekker, Inc.
6. Digital Protection, Protective Relaying from Electromechanical to Microprocessor by Singh L.P, John Wiley & Sons.

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

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

Course Objectives

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

Course Content

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

Course Outcomes

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

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

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

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

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

Books and References

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

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

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

Course Objectives

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

Course Content

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

Course Outcomes

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

CO1: Identify different types of optimization techniques and problems.

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

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

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

Books and References

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

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

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

Course Objectives

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

Course Content

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

Course Outcomes

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

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

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

CO4: Assess the results obtained by solving above problems.

Books and References

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

Course Name: Power System Dynamics & Stability **Course Code: EE-721** **Course Type: Programme Elective-II**
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.
Books and References 1. Power System Stability and Control by P. Kundur, Mc Graw Hill. 2. Power System Dynamics by K.R. Padiyar, B S Publications. 3. Power System Control and Stability by P.M Anderson and A.A Fouad, IEEE press power engineering series

Course Name: Hydro Power Station Practice
Course Code: EE-722
Course Type: Programme Elective-II

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

Planning and Layout: Planning and layout of electrical equipment's in hydro power station. Governing of Water 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.

Books and References

1. Hydro Electric Engg. Practice Vol. I, II, and III by J. Guthrie Brown, Blackie.
2. Elements of Electrical Power Station Design by M V Deshpande, Prentice Hall of India.
3. Power System Stability and Control by Prabha Kundur, Mc-Graw Hill.
4. Handbook of Hydroelectric Engineering by P.S. Nigam, Nem Chand & Bros, Roorkee.

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

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

Course Objectives

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

Course Content

Understanding, analysis and application of electrical energy management-measurement and accounting techniques-consumption patterns- conservation methods-application in industrial cases. System approach and End use approach to efficient use of Electricity; Electricity tariff types; Energy auditing: Types and objectives-audit instruments-ECO assessment and Economic methods-specific energy analysis-Minimum energy paths-consumption models-Case study. Electric motors-Energy efficient controls and starting efficiency- Motor Efficiency and Load Analysis- Energy efficient / 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

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

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

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

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

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

Books and References

1. Handbook on Energy Audit and Environment Management by Y P Abbi and Shashank Jain, TERI.
2. Handbook of Energy Audits Albert Thumann by William J. Younger, Terry Niehus
3. Industrial Energy Management: Principles and Applications by Giovanni Petrecca, The Kluwer international series -207.
4. Guide to Electric Load Management by Anthony J. Pansini, Kenneth D. Smalling, Pennwell Pub.
5. Energy-Efficient Electric Motors and Their Applications by Howard E. Jordan,., Plenum Pub Corp.
6. Energy Management Handbook by Turner, Wayne C., Lilburn, The Fairmont Press.
7. Handbook of Energy Audits by Albert Thumann, Fairmont Pr.
8. Recommended Practice for Energy Conservation and cost-effective planning in Industrial facilities IEEE Bronze Book, USA.
9. Plant Engineers and Managers Guide to Energy Conservation by Albert Thumann, P. W, Seventh, Terre Haute.

Course Name: **Power System Simulation 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. Using Lambda-iteration technique Economic load dispatch with/without losses of standard test systems 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 of a given problems such as OPF, economic load dispatch etc.

CO3: Do the analysis of various power system problems and find their solution using MATLAB.

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

Contact Hours/Week: **4L** 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 with and without line losses, lambda iteration method, gradient method, lambda iteration method, gradient method, Newton's method, Dynamic programming method, binary search method, base point and participation factors, transmission losses, a two generation system 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, hydro constraints, must run, fuel constraints, priority list method, Dynamic programming method and Lagrange relaxation methods, generation with limited energy supply, take or pay fuel supply contract, composite generation production cost function, gradient search techniques, hydrothermal co-ordination, long range hydro scheduling, Short-range hydro scheduling, scheduling energy, short term hydrothermal scheduling, lambda-gamma iteration method, gradient method, cascaded hydro plants, pumped storage hydro scheduling, optimal power flow introduction, Solution of optimal power flow by gradient and Newton's method, linear sensitivity analysis, sensitivity coefficients of an AC network model linear programming methods, 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 implementation.

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.

Books and References

1. Power generation operation and control by A.J wood and B.F Wollenberg, Wiley.
2. Electrical Energy system theory by O.I. Elgerd. Tata cGraw Hill, Delhi.
3. Power Systems Analysis by Hadi Saadat, McGraw-Hill Inc.
4. Power system operation and control by K Uma Rao, Wiley-India.

Course Name: Power System Restructuring & 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. Competitive electricity market: 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). 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.

Books and References

1. Power System Restructuring and Deregulation by Loi Lei Lai, John Wiley & Sons Ltd.
2. Understanding Electric Utilities and Deregulation by Lorrin Philipson and H. Lee Willis, Marcel Dekker Inc, New York, CRC Press.
3. Power System Restructuring Engineering & Economics by Marija llic by Francisco Galiana and Lestor Fink, Kulwer Academic Publisher, USA.

Course Name: **FACTS Devices & Power Transmission** Course Code: **EE-623** Course Type: **Core**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To learn the concept of power flow control through various power electronic controllers including state of art FACTS controllers, operational aspects, capabilities and their integration in power flow analysis.
- To learn the effectiveness of Filters in distribution system for harmonic mitigation etc.
- Application of FACTS controllers as case studies in the Power System

Course Content

FACTS concepts and General system considerations: Introduction to power semiconductor devices, Diode, GTO, MOSFET, IGBT, MOS Controlled Thyristor, Transmission interconnection, power flow in ac system, power flow and dynamic stability considerations, Basic of FACTS controllers, shunt, series, combined and other controllers, FACTS technology, HVDC or FACTS. Voltage Source Converters: Basic concepts, single phase full wave bridge converter operation, three phase full wave bridge converter, sequence of valve conduction process in each phase leg, transformer connections for 12 pulse operation, three level voltage sourced converter, PWM converter. Self and Line Commutated Current Sourced Converters: Basic concepts, three phase full wave diode rectifier, thyristor-based converter, Rectifier and inverter operation valve voltage and commutation failure, Current sourced versus voltage sourced converters. Harmonics and Filters: Harmonics on ac side and dc side of converter, characteristics and uncharacteristic harmonics, troubles caused by harmonics, harmonic filters. FACTS Devices: Introduction: objectives of shunt compensation, methods of controllable Var Generation, static Var Compensators, SVC and STATCOM, Static series compensators, TSSC, TCSC and SSC. Combined Compensators: Introduction, Unified power flow controller (UPFC), conventional power control capabilities, real and reactive power flow control, comparison of UPFC to series compensators, control structure, dynamic performance. Interline power flow controller basic operating principles, control structure, application considerations. Application Examples: Case studies of standard power systems with FACTS.

Course Outcomes

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

CO1: Modeling concepts of commonly used FACTS controllers will be understood.

CO2: How FACTS controllers improve the power flow in the system and their incorporation in the system shall be clear.

CO3: To understand how FACTS controllers, enhance the power system stability.

CO4: Student will learn how FACTS devices improve the power system operation and damp the system oscillations.

CO5: Application of harmonics filters for harmonic mitigation shall be understood.

Books and References

1. Understanding FACTS concepts and Technology of Flexible AC Transmission system by N.G. Hingorni and L. Ayugyi, standard Publication New Delhi.
2. Facts Controllers in Power Transmission and Distribution by K. R. Padiyar, New Age International Publishers
3. Thyristor-Based FACTS Controllers for Electrical Transmission Systems by Mohan Mathur and Rajiv K. Verma, Wiley Student Edition
4. Flexible AC Transmission Systems: Modelling and Control by Zhang, X. P., Rehtanz, C. and Pal, B., Springer
5. Research papers related to FACTS in power system

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

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

Course Objectives:

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

Course Content

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

Course Outcomes

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

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

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

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

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

Books and References

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

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

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

Course Objectives:

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

Course Content

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

Course Outcomes

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

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

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

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

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

Books and References

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

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

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

Course Objectives

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

Course Content

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

Course Outcomes

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

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

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

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

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

Books and References:

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

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

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

Course Objectives

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

Course Content

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

Course Outcomes

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

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

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

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

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

Books and References

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

Course Name: SCADA Systems and Applications
Course Code: EE-727
Course Type: Programme Elective-IV

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

Course Objectives

- The course provides an introduction to the role of Computers and Communication in Electrical Power Engineering. Supervisory Control and Data Acquisition (SCADA) are strongly linked and associated with each other.
- This course provides an introductory course material for power system automation and recent advances in technological aspects of computers, communications in networking and power system security.
- To give the knowledge about the various components of power system 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 System Components: Schemes- Remote Terminal Unit (RTU), Intelligent Electronic Devices (IED), Programmable Logic Controller (PLC), Communication Network, SCADA Server, SCADA/HMI Systems. SCADA Architecture: 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. Industries - oil, gas and water. Case studies, Implementation, Simulation Exercises.

Course Outcomes

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

CO1: Aware about the importance of energy conservation coupled with new international standards and regulations a scrambling to find a simple, cost-effective way to monitor and control their energy consumption.

CO2: Computer Methods in Power System Applications and Monitoring and supervisory for the existing power system structure.

CO3: Able to Understand the different types of operator interfaces and economic benefits of SCADA systems.

CO4: Describe the difference between soft and hard Human Machine Interfaces (HMI) and the functions of Remote Terminal Units.

Books and References

1. SCADA-Supervisory Control and Data Acquisition by Stuart A. Boyer, Instrument Society of America Publications, USA..
2. Deon Reynders: Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems by Gordon Clarke, Newnes Publications, Oxford, UK.
3. Cybersecurity for SCADA systems by William T. Shaw, PennWell Books.
4. Practical SCADA for industry by David Bailey, Edwin Wright, Newnes.
5. A guide to utility automation: AMR, SCADA, and IT systems for electric power by Michael Wiebe, PennWell.

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

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

Course Objectives

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

Course Content

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

Course Outcomes

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

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

Books and References

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

Course Name: Power System Design & Analysis Lab
Course Code: EE-624

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

Course Objectives

- An ability to design a system, component, process to meet desired needs with in realistic constraints.
- To provide skills for developing Simulink model of practical problems and analyzing their results on MATLAB.
- To able the students to demonstrate a mastery in the area of 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: Working of Power system problems and model them in MATLAB.

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

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