Academic Program: PG

Academic Year 2019-20 Syllabus

I & II Semester M.Tech

Power Systems Engineering

SHRI DHARMASTHALA MANJUNATHESHWARA COLLEGE OF ENGINEERING & TECHNOLOGY,
DHARWAD – 580 002

(An Autonomous Institution recognized by AICTE & Affiliated to VTU, Belagavi)

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SDM College of Engineering & Technology, Dharwad

It is certified that the scheme and syllabus for I &II semester M.Tech in Power Systems Engineering is recommended by the Board of Studies of Electrical and Electronics Engineering Department and approved by the Academic Council, SDM College of Engineering &Technology, Dharwad. This scheme and syllabus will be in force from the academic year 2018-19 till further revision.

Principal Dean (Academic Program) Chairman BoS & HoD

SDM College of Engineering & Technology, Dharwad
Department of Electrical Engineering
*(Our motto: Professional **C**ompetence with **P**ositive **A**ttitude)*

College Vision and Mission

Vision:

To develop competent professionals with human values.

Mission:

1. To have contextually relevant Curricula.
2. To promote effective Teaching Learning Practices supported by Modern Educational Tools and Techniques.
3. To enhance Research Culture.
4. To involve Industrial Expertise for connecting classroom content to real life situations.
5. To inculcate Ethics and impart soft-skills leading to overall Personality Development.

SDMCET- Quality Policy

- In its quest to be a role model institution, committed to meet or exceed the utmost interest of all the stake holders.

SDMCET- Core Values

- Competency
- Commitment
- Equity
- Team work and
- Trust

Department Vision and Mission

Vision:

To develop globally acceptable Electrical and Electronics Engineering professionals with human values.

Mission:

1. Adopting the state of the art curricula
2. Practicing effective and innovative teaching-learning methodologies
3. Initiating complementary learning activities to enhance competence
4. Inculcating positive attitude and commitment to society.

Program Educational Objectives (PEOs):

The Program Educational Objectives (PEOs) :

I. To prepare graduates who will be successful professionals in industry, government, academia, research, entrepreneurial pursuit and consulting firms

II. To prepare graduates who will contribute to society as broadly educated, expressive, ethical and responsible citizens with proven expertise

III. To prepare graduates who will achieve peer-recognition; as an individual or in a team; through demonstration of good analytical, research, design and implementation skills

IV. To prepare graduates who will thrive to pursue life-long reflective learning to fulfill their goals

Program Outcomes (POs):

PO1: An ability to independently carry out research / investigation and development work to solve practical problems.

PO2: An ability to write and present a substantial technical report / document.

PO3: Student should be able to demonstrate a degree of mastery over the area of power systems engineering

PO4: Exposure to the state of the art practices in the domain of power systems engineering

Scheme of Teaching and Examination

I-Semester M. Tech. (Power Systems Engineering)

Course Code	Course Title	Teaching		Examination				
		L-T-P (Hrs/Week)	Credits	CIE	Theory (SEE)		Practical (SEE)	
				Max. Marks	*Max. Marks	Duration in hours	Max. Marks	Duration in hours
18PMAC100	Applied Mathematics	4-0-0	4	50	100	3		
18PEPSC100	Advanced Power System Analysis	4-0-0	4	50	100	3		
18PEPSEXXX	Elective 1	4-0-0	4	50	100	3		
18PEPSEXXX	Elective 2	4-0-0	4	50	100	3		
18PEPSEXXX	Elective 3	4-0-0	4	50	100	3		
18PEPSL101	Power System Laboratory-I	0-0-3	2	50			50	3
18PEPSL102	** Seminar	0-0-3	1	100				
	Total	**20-0-6**	**23**	**400**	**500**		**50**	

CIE: Continuous Internal Evaluation **SEE**: Semester End Examination

L: Lecture **T**: Tutorials **P**: Practical

***** SEE for theory courses is conducted for 100 marks and reduced to 50 marks.

****** Seminar is to be conducted every week and 2-3 students/week will present a topic from emerging areas in power systems preferably the contents not studied in their regular courses. The seminar shall be evaluated by 3 faculty members having specialization in power system and allied areas.

Course Code	Elective Courses
18PEPSE125	Power System Modeling & Dynamics
18PEPSE126	Advanced Power System Protection
18PEPSE127	EHV AC Transmission
18PEPSE128	Linear and Nonlinear Optimization
18PEPSE129	Modeling and Analysis of Electrical Machines
18PEPSE130	Power Quality Issues and Mitigation Techniques

Scheme of Teaching and Examination

II-Semester M. Tech. (Power Systems Engineering)

Course Code	Course Title	Teaching		Examination				
		L-T-P (Hrs/Week)	Credits	CIE	Theory (SEE)		Practical (SEE)	
				Max. Marks	*Max. Marks	Duration in hours	Max. Marks	Duration in hours
18PEPSC200	Economic Operation & Control of Power System	4-0-0	4	50	100	3		
18PEPSC201	Distribution System Design & Control	4-0-0	4	50	100	3		
18PEPSEXXX	Elective course-IV	4-0-0	4	50	100	3		
18PEPSEXXX	Elective course-IV	4-0-0	4	50	100	3		
18PEPSEXXX	Elective course-VI	4-0-0	4	50	100	3		
18PEPSL202	Power System Laboratory-II	0-0-3	2	50			50	3
18PEPSL203	**Seminar	0-0-3	1	100				
	Total	**20-0-6**	**23**	**400**	**500**		**50**	

CIE: Continuous Internal Evaluation **SEE**: Semester End Examination

L: Lecture **T**: Tutorials **P**: Practical

***** SEE for theory courses is conducted for 100 marks and reduced to 50 marks.

****** Seminar is to be conducted every week and 2-3 students/week will present a topic from emerging areas in power systems preferably the contents not studied in their regular courses. The seminar shall be evaluated by 3 faculty members having specialization in power system and allied areas.

Course Code	Elective Courses
18PEPSE225	Reactive Power Management in Power System
18PEPSE226	Artificial Intelligence Techniques to Power System
18PEPSE227	Power System SCADA
18PEPSE228	HVDC Power Transmission
18PEPSE229	Fundamentals of Smart Grid Technology
18PEPSE230	Distributed Generation and Micro Grids

I - Semester M. Tech. (Power Systems Engineering)

18PMAC100	**Applied Mathematics**	**(4-0-0) 4**

Contact Hours: 52

Course Learning Objectives (CLOs):

Study Numerical methods to solve algebraic, transcendental equations. Learn to solve system of linear equations. Learn the idea of random variable and probability distribution. To prepare the students to formulate and solve linear programming problem. Introducing students to the fundamental concepts of Graph theory, linear algebra culminating in abstract vector spaces and linear transformations

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1 to 4)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Use Numerical methods to solve algebraic and transcendental equations.	1		2
CO-2	Calculate Eigen values and Eigen vectors of real symmetric matrices. Solve system of Linear Algebraic equations.	1		2
CO-3	Solve linear and non-linear equation.	1	3	2
CO-4	Learn the idea of random variables (discrete/continuous) and probability distributions in analyzing the probability models.	1		2
CO-5	Learn the Concept of graph theory in engineering problems.	1	3	2
CO-6	Explain Algebra of linear transformations.	1	3	2

POs	**PO-1**	**PO-2**	**PO-3**	**PO-4**
Mapping Level	3	1	2	

Prerequisites: Knowledge of Elementary concepts of Algebra, Basic Probability theory, Basics of matrices.

Contents:

I. Numerical Methods

Solution of algebraic and transcendental equations Muller method (no derivation), Chebyshev method, polynomial equations Birge–Vieta method and Bairstow's method.

Eigen value problems

Gerschgorian circle, Eigen values and Eigen vectors of real symmetric matrices –Jacobi method, Givens method. **10Hrs.**

II. Linear and Non Linear Programming

Linear programming- formulation of the problem, graphical method, simplex method, artificial variable technique -M-method. Non Linear Programming – Constrained extremal problems-Lagranges multiplier method- Kuhn-Tucker conditions and solutions. **10Hrs.**

III. Probability

Review of basic probability theory. Definitions of random variables and probability distributions, probability mass and density functions, expectation, characteristic functions Binomial, Poisson, Exponential examples, Marginal and conditional distribution, Elements of stochastic processes. **12 Hrs.**

IV. Graph Theory: Basic terminologies, types of graphs, sub graphs, graphs isomorphism, connected graphs-walks, paths, circuits, connected and disconnected graphs, operations on graphs, Eulerian paths and circuits, Hamiltonian paths and circuits, applications of graphs. **10Hrs.**

V. Linear Algebra: Vector spaces, linear dependent, independence, basis and dimension, elementary properties, examples.

Linear Transformations: Definition, properties, range and null space, rank and nullity, algebra of linear transformations- invertible, singular and non-singular transformations, representation of transformations by matrices.

10Hrs.

Reference Books:

1) M K Jain, S R K Iyengar and R K Jain, "Numerical Methods for Scientific and Engineering Computations", New Age International, 2004.
2) Dr. B.S. Grewal, "Higher Engineering Mathematics", 41stEdition, Khanna Publishers, 2011.
3) Narsingh Deo, "Graph Theory with Applications to Engineering and Computer Science", PHI, 2012.
4) Kenneth Hoffman and Ray Kunze, "Linear Algebra", 2ndEdition, PHI, 2011.

18PEPSC100	Advanced Power System Analysis	(4-0-0) 4

Contact Hours: 52

Course Learning Objectives (CLOs):

1. Study various methods of load flow and their advantages and disadvantages
2. Understand how to analyse various types of faults in power system
3. Understand and analyse various stability aspects of power system.
4. Study voltage instability phenomenon
5. Understand need of state estimation and study simple algorithms for state estimation

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1 to 4)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level(1)**
CO1	Perform load flow studies for a multi-machine system	1	3	2
CO2	Analyze for various faults in power system	1	3	2
CO3	Explain stability aspects of power system and voltage stability phenomenon	1	3	2
CO4	Locate the state of power system using algorithms	1	3,4	2

POs	**PO-1**	**PO-2**	**PO-3**	**PO-4**
Mapping Level	3.0	1.0	2.0	2.0

Prerequisites: Power System Analysis

Contents:

I. Load Flow:

Overview of Newton-Raphson, Gauss-Siedel, Fast De-coupled methods, convergence properties, sparsity techniques, handling Q_{max} violations in constant matrix, inclusion in frequency effects, AVR in load flow, handling of discrete variable in load flow. **10 Hrs.**

II. Fault Analysis:

Simultaneous faults, open conductor faults, generalized method of fault analysis. **10 Hrs**

III. Stability Aspects of Power System:

Steady state stability of a multi-machine power system, Transient Stability Studies- Swing equation, RungeKutta Method, Long term transient stability studies. Dynamic Stability Studies- Concept, effect of saliency and saturation on stability, Demello-Concordia model, dynamic stability assessment using torque angle loop analysis, effect of excitation on stability. **14 Hrs.**

IV. Voltage Stability:

Voltage collapse, P-V curve, multiple power flow solution, continuation power flow, optimal multiples load flow, voltage collapse proximity indices. **09 Hrs.**

V. State Estimation: Sources of errors in measurement, virtual and Pseduo, Measurement, Observability, Tracking state estimation, WSL method, bad data correction. **09 Hrs.**

Reference Books:

1) J. J. Grainger & W. D. Stevenson, "Power System Analysis", McGraw Hill, 2003
2) A. R. Bergen & Vijay Vittal, "Power System Analysis", Pearson, 2000.
3) L. P. Singh, "Advanced Power System Analysis and Dynamics", New Age International, 2006.
4) G. L. Kusic, "Computer Aided Power System Analysis", Prentice Hall India, 1986.
5) A. J. Wood, "Power generation, operation and control", John Wiley, 1994
6) P. M. Anderson, "Faulted power system analysis", IEEE Press, 1995
7) Prabha Kundur, "Power System Stability and control, 1st Edition, 1994
8) Nagarath & Kothari, Modern Power System Analysis", 4th Edition, TMH, 2011.

18PEPSE125	Power System Modeling and Dynamics	(4-0-0) 4

Contact Hours: 52

Course Learning Objectives (CLOs):

1. To impart knowledge on dynamic modeling of a synchronous machine excitation and prime mover controllers.
2. To describe the modeling of transmission lines, SVC and loads.
3. To explain the dynamics of single machine connected to infinite bus.
4. To describe the analysis of single systems and evaluation of transient stability.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		Mapping to POs(1 to 4)		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO1	Model and analyze synchronous machines and transients respectively	1	3	2
CO2	Develop appropriate models of individual power system elements for power system dynamics studies.	1, 3	4	2
CO3	Model and analyze single machine connected to infinite bus for transient stability.	1, 3	4	2
CO4	Use compensation technique for smooth operation of power system and decide on choosing necessary power system stabilizers	1	3, 4	2

POs	PO-1	PO-2	PO-3	PO-4
Mapping Level	3	1	2.5	2

Prerequisites: Computer Techniques in Power System, Electric machines, Electric Power generation and transmission

Contents:

I. Modeling of Synchronous Machine:

Review of classical methods, modeling of Synchronous machine, Park's Transformation, Transformation of flux linkages, Transformation of stator voltage equations and rotor equations, Analysis of steady state performance, per unit quantities, Equivalent circuits of synchronous machine - determination of parameters of equivalent circuits. **14 Hrs.**

II. Excitation System and prime mover controllers:

Excitation system modeling, excitation systems block Diagram system representation by state equations, Prime mover control system. **06 Hrs.**

III. Transmission lines and loads:

Modeling of transmission lines, D-Q transformation, modeling of SVC and loads, modeling of Induction motors. **06 Hrs.**

IV. Dynamics of a Synchronous Generator Connected to Infinite Bus:

System model, Synchronous machine model, stator equations, rotor equations, Synchronous machine model x x, calculation of Initial conditions. **10 Hrs.**

V. Analysis of Single Machine System:

Small signal analysis with block diagram, Representation characteristic equation and application of Routh Hurwitz criterion, Synchronizing and damping torque analysis, small signal model State equations. **09 Hrs.**

VI. Application of Power System Stabilizers:

Basic concepts in applying PSS, Control signals, structure and tuning of PSS, washout circuit, dynamic compensator analysis of single machine infinite bus system with and without PSS. **07 Hrs.**

Reference Books:

1) K. R. Padiyar, “Power System Dynamics”, B.S. Publications, Hyderabad

2) P. M. Anderson and A.A. Fouad, “Power System Control and Stability”, 2nd Edition, B. S. Publications Hyderabad

3) Peter W. Sauer & M. A. Pai, “Power System Dynamics and Stability” Prentice Hall

18PEPSE126	Advanced Power System Protection	(4-0-0) 4

Contact Hours: 52

Course Learning Objectives (CLOs):

1. To introduce the components of the Power System to be protected.
2. To discuss hardware resource required to develop the digital relay.
3. To introduce basics of DSP hardware, algorithms and relaying schemes to protect power system.
4. To introduce to the concept of existing digital relays for motor protection, transformer protection and other components in power system

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs (1 to 4)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO1	Apply the knowledge of hardware to develop the digital relay for different components of Power System	4	3	2
CO2	Develop DSP based relay algorithms	4	3	2
CO3	Apply concepts of programming to simulate and study the behavior of developed hardware resource to protect components of power system.	1, 4	3	2
CO4	Apply concepts of Digital Protection to protect transformers, Motors and Busbar.	4	3	2

POs	**PO-1**	**PO-2**	**PO-3**	**PO-4**
Mapping Level	3	1	2	3

Prerequisites: Power system protection

Contents:

I. Introduction to Computer Relaying

Development of computer relaying, Historical background, Expected benefits of computer relaying, Computer relay architecture, Protection Generations ,Analog to digital converters, Anti-aliasing filters, Digital Signal Processing, Hierarchical Structure of Protection and Control. **10 Hrs.**

II. Relaying practices

Introduction to protection systems, Functions of a protection system, Protection transmission lines, Performance of current and voltage transformers. **06 Hrs.**

III Relaying Algorithm

Algorithms Based on Undistorted single frequency sine wave:

Mann and Morrison Algorithm, Three Sample technique, First and second derivative algorithm, two sample technique

Algorithms Based on Solution of Differential Equation:

Differential Equation Algorithm, Solution of Differential Equation Algorithm using Numerical Integration ,Application of Differential Equation Algorithm to Three-Phase Line. **Algorithms Based on Least Squared Error:** LSQ Technique, LSQ and Pseudo –Inverse, LSQ Algorithm By Sachdev.

15 Hrs.

IV Digital Protection of transformers and machines:

Introduction, Power transformer algorithms, Generator protection, Motor protection. **06 Hrs.**

V. Digital Bus Differential Protection

Introduction, Busbar Protection Techniques, New Differential Bus Protection Algorithm, Differential Principle, CT Saturation Detection. **06 Hrs.**

VI. Hardware organization in integrated systems

The nature of hardware issues, Computers for relaying, The substation environment, Industry environmental standards, Countermeasures against EMI, Supplementary Equipment. **05 Hrs.**

Reference Books:

1) Arun G. Phadke, James S. Thorp, “Computer Relaying for Power Systems”, John Wiley and Sons Inc, 2nd Edition, 2009
2) A.T. Johns and S. K. Salman, “Digital Protection for Power Systems” Peter Peregrinus Ltd,
3) S. R. Bhide, “Digital Power System Protection” PHI Learning Private Limited, 1st Edition, 2013
4) Waldemar Rebizant, Janusz Szafran, Andrzej Wiszniewski, “Digital Signal Processing in Power System Protection and Control, Springer, 1st Edition, 2011
5) GER-3984 Reference Manual, General Electric, Digital Low-Impedance Bus Differential Protection: Principles and Approaches

18PEPSE127	EHV AC Transmission	(4-0-0) 4

Contact Hours: 52

Course Learning Objectives (CLOs):

At the end of the course, the students will be able to

1. Select the transmission voltage level
2. Calculate Line parameters for bundled conductors and analyze the performance.
3. Calculate voltage gradient of bundled conductors
4. Evaluate the corona effects, interference on radio waves and suggest remedies to overcome the same.
5. Calculate electrostatic field of EHV AC lines
6. Analyze travelling waves
7. Analyze compensated devices for voltage control.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1 to 4)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level(1)**
CO1	Describe recent trends in power transmission at extra high voltages	1, 2	3, 4	
CO2	Estimate the voltage gradients on conductor and corona loss, analyze the propagation of travelling waves and standing waves on transmission lines.	1, 2	3, 4	
CO3	Distinguish the various protection methods for lightning and switching surges on transmission lines.	1, 2	3, 4	
CO4	Design EHV line based on steady state limits and assess the effect of electrostatic and magnetic fields of EHV lines on the human beings and the surrounding.		1, 2	3, 4

POs	**PO-1**	**PO-2**	**PO-3**	**PO-4**
Mapping Level	2.75	2.75	1.75	1.75

Prerequisites: High Voltage Engineering

Contents:

I. Transmission Line Trends and Preliminaries: Role of EHV AC Transmission, Standard Transmission Voltages, Average Values of Line Parameters, Power-Handling Capacity and Line Loss, Examples of Giant Power Pools and Number of Lines, Costs of Transmission Lines and Equipment, Mechanical Considerations in Line Performance. **04 Hrs**.

II. Calculation of Line and Ground Parameters: Resistance of Conductors, Temperature Rise of Conductors and Current-Carrying Capacity, Properties of Bundled Conductors, Inductance of EHV Line Configurations, Line Capacitance Calculation, Sequence Inductances and Capacitances, Line Parameters for Modes of Propagation, Resistance and Inductance of Ground Return. **08 Hrs**.

Voltage Gradients of Conductors**:** Electrostatics, Field of Line Charges and Their Properties, Charge-Potential Relations for Multi-Conductor lines, Surface Voltage Gradient on Conductors, Gradient Factors and Their Use. **04 Hrs.**

III. Corona: I2R Loss and Corona Loss, Corona-Loss formulae, Attenuation of Travelling Waves due to Corona Loss, Audible Noise: Generation and Characteristics, Limits for Audible Noise. Generation of Corona Pulses and their Properties, Properties of Pulse Trains and Filter Response, Limits for Radio Interference Fields. **04 Hrs.**

IV. Theory of Travelling Waves and Standing Waves: Travelling Waves and Standing Waves at Power Frequency, Differential Equations and Solutions for General Case, Standing Waves and Natural Frequencies, Open-Ended Line: Double-Exponential Response, Open-Ended Line: Response to Sinusoidal Excitation, Line Energization with Trapped-Charge Voltage, Corona Loss and Effective Shunt Conductance, The Method of Fourier Transforms, Reflection and Refraction of Travelling Waves, Transient Response of Systems with Series and Shunt Lumped Parameters and Distributed Lines, Principles of Travelling-Wave Protection of EHV Lines. **08 Hrs.**

V. Lightning and Lightning Protection: Lightning Strokes to Lines, Lightning-Stroke Mechanism, General Principles of the Lightning-Protection Problem, Tower-Footing Resistance, Insulator Flashover and Withstand Voltage, Probability of Occurrence of Lightning-Stroke Currents, Lightning Arresters and Protective Characteristics, Dynamic Voltage Rise and Arrester Rating, Operating Characteristics of Lightning Arresters, Insulation Coordination Based on Lightning. **06 Hrs.**

VI. Over voltages in EHV Systems Caused by Switching Operations: Origin of Over voltages and Their Types, Short-Circuit Current and the Circuit Breaker, Recovery Voltage and the Circuit Breaker, Over voltages Caused by Interruption of Low Inductive Current, Interruption of Capacitive Currents, Ferro-Resonance Over voltages, Calculation of Switching Surges—Single

Phase Equivalents, Distributed-Parameter Line Energized by Source, Generalized Equations for Single- Phase Representation, Generalized Equations for Three-Phase Systems, Inverse Fourier Transform for the General Case, Reduction of Switching Surges on EHV Systems, Experimental and Calculated Results of Switching-Surge Studies. **08 Hrs.**

VII. Design of EHV Lines Based upon Steady-State Limits and Transient Over voltages: Introduction, Design Factors under Steady State, Design Examples: Steady-State Limits, Design Examples I to IV, Line Insulation Design based upon Transient Over voltages. **06 Hrs.**

VIII. Electrostatic and Magnetic Fields of EHV Lines: Electric shocks and threshold current, Capacitance of a long object, electrostatic field of ac lines, Effect of high electrostatic fields on humans, animals and plants, Magnetic fields, magnetic field of three phase lines, Effect of power frequency magnetic field on human health. **04 Hrs.**

Reference Books:

1) Rakosh Das Begamudre, “Extra High Voltage AC Transmission Engineering”, New Age International Publishers. 4^{th} Edition, 2011
2) EHV Transmission line reference book-Edition Electric Institute (GEC) 1986.

18PEPSE128	**Linear and Nonlinear Optimization**	**(4-0-0) 4**

Contact Hours: 52

Course Learning Objectives (CLOs):

1. Provide introduction to optimization.
2. Explanation to classification of optimization problems.
3. Explanation for linear programming and solution of LPP problem.
4. Explanation for nonlinear programming and solution of nonlinear programming problem by one dimensional minimization method.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		Mapping to POs(1 to 4)		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO1	Explain the optimization methods used in engineering studies		1	2
CO2	Identify the suitable techniques to be used for solving a given optimization problem.	1	3	2

CO3	Apply Linear and nonlinear programming techniques for the solution of optimization problem	1,4	3	2

POs	PO-1	PO-2	PO-3	PO-4
Mapping Level	2.67	1	2	3

Prerequisites: Linear and Nonlinear Optimization Techniques

Contents:

I. Optimization:

Introduction, historical development, engineering applications of optimization, statement of an optimization problem, design vector, design constraints, constraint surface, objective function, objective function surfaces, classification of optimization problems based on existence of constraints, nature of the design variables, physical structure of the problem, nature of the equations involved, nonlinear and linear programming problem(NLP and LPP), permissible values of the design variables, deterministic nature of the functions, number of objective functions, optimization techniques. **09 Hrs.**

II. Classification of Optimization Problems:

Introduction, single variable optimization, multivariable optimization with no constraints, semi-definite case, saddle point, multivariable optimization with equality constraints, solution by direct substitution, by the method of constrained variation and by the method of Lagrange multipliers, multivariable optimization with inequality constraints, Kuhn-Tucker conditions, constraint qualification, formation of LLP, graphical method. **09 Hrs.**

III. Linear Programming-I:

Introduction, applications of linear programming, standard form of a LPP, geometry of LPP, definitions and theorems, solution of a system of linear simultaneous equations, pivotal reduction of a general system of equations, motivation of the simplex method, simplex algorithm, identifying an optimal point, improving a non-optimal basic feasible solution, two phases of the simplex method. **09 Hrs.**

IV. Linear Programming-II

Revised simplex method, duality in linear programming; symmetric and primal-dual relations, primal-dual relations when the primal is in standard form, duality theorems, dual simplex method, decomposition principle, sensitivity or post-optimality analysis, changes in right-hand-side constants bi, changes in the cost coefficients Cj, addition of new variables, changes in the constraint coefficients

a_{ij}, addition of constraints. Transportation problem, Karmarkar's method, statement of the problem, conversion of an LPP into required form, algorithm, quadratic programming **09 Hrs.**

V. Non-Linear Programming - One Dimensional Minimization Methods:

Introduction, Unimodal function, Unrestricted search with fixed step size and accelerated step size, exhaustive search, dichotomous search, interval halving method, Fibonacci method, golden section method, comparison of elimination methods, interpolation methods, quadratic and cubic, direct root methods, Newton, Quasi-Newton and Secant methods, practical considerations. **07 Hrs.**

VI. Non-Linear Programming - Unconstrained Minimization Methods:

Introduction, direct search methods: random search methods, grid search, univariate, pattern directions, Hook and Jeeve's method, Powel's methods, Rosen brock's method of rotating coordinates, simplex methods, reflection, expansion, contraction, indirect search methods, gradient of a function, Cauchy method, conjugate gradient methods, Newton's method, Marquadrant method, quasi- Newton methods, Davidon-Fletcher-Powel method, Broydon-Fletcher – Goldfarb – Shanno method, test functions, constrained and unconstrained optimization techniques, direct and indirect methods. **09 Hrs.**

Reference Books:

1) Singiresu S Rao (S. S. Rao), "Engineering Optimization", John Wiley and Sons Inc, 1996
2) David Mautner Himmelblau, "Applied Nonlinear Programming", McGraw-Hill, 1972.
3) A. P. Verma, "Operation Research", S. K. Kataria & Sons, 2009

18PEPSE129 Modeling and Analysis of Electrical Machines (4-0-0) 4

Contact Hours: 52

Course Learning Objectives (CLOs):

To provide basic concepts of modeling of dc and ac machines.

1. To provide knowledge of theory of transformation of three phase variable to two phase variable.
2. To analyze the steady state and dynamic state operation of three-phase induction machines using transformation theory based mathematical modeling.
3. To provide modeling concepts of single phase and three phase transformers.
4. To analyze the steady state and dynamic state operation of three-phase synchronous machines using transformation theory based mathematical modeling.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		Mapping to POs(1 to 4)		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO1	Apply the knowledge of mathematical modeling of electrical rotating machines and transformers		1	2
CO2	Develop dynamic and small signal models of induction motor using the modeling techniques.	1,3		2
CO3	Develop mathematical model of single phase transformers.	1,3		2
CO4	Model three phase synchronous machines using transformation theory and perform dynamic analysis.	1,3	4	2

POs	PO-1	PO-2	PO-3	PO-4
Mapping Level	2.75	1	3	2

Prerequisites: Basic of AC and DC machines

Contents:

I. Basic Concepts of Modeling:

Basic two pole machine representation of commutator machines, 3-phase synchronous machine with and without damper bar and 3-phase induction machine, Kron's primitive machine-voltage, current and torque equations. **05 Hrs**.

II. DC Machine Modeling:

Mathematical model of separately excited DC motor-steady state and transient state analysis, sudden application of inertia load, transfer function of separately excited DC motor, mathematical model of dc series motor, shunt motor, linearization techniques for small perturbations. **08 Hrs.**

III. Reference Frame Theory:

Real time model of a two phase induction machine, transformation to obtain constant matrices, three phase to two phase transformation, power equivalence. **05 Hrs.**

IV. Dynamic Modeling of Three Phase Induction Machine:

Generalized model in arbitrary frame, electromagnetic torque, deviation of commonly used induction motor models-stator reference frames model, rotor reference frames model, synchronously rotating reference frames model, equations in flux linkages, per unit model, dynamic simulation. **08 Hrs.**

V. Small Signal Equations of the Induction Machine:

Derivation of small signal equations of induction machine, space phasor model, DQ flux linkages model derivation, control principle of the induction motor. **04 Hrs**.

VI. Transformer Modeling:

Introduction, single phase transformer model, three phase transformer connections, per phase analysis, normal systems, per unit normalization, per unit three phase quantities, change of base, per unit analysis of normal system, regulating transformers for voltage and phase angle control, auto transformers, transmission line and transformers. **08 Hrs.**

VII. Modeling of Synchronous Machines:

Introduction, voltage equations and torque equation in machine variables, stator voltage equations in arbitrary and rotor reference frame variables, Park's equations, torque equations in substitute variables, rotor angle and angle between rotors, per unit system, analysis of steady state operation. **07 Hrs.**

VIII.Dynamic Analysis of Synchronous Machines:

Dynamic performance during sudden change in input torque and during a 3-phase fault at the machine terminals, approximate transient torque versus rotor angle characteristics, comparison of actual and approximate transient torque-angle characteristics during a sudden change in input torque; first swing transient stability limit, comparison of actual and approximate transient torque-angle characteristics during a 3-phase fault at the machine terminals, critical clearing time, equal area criterion, computer simulation. **07 Hrs.**

Reference Books:

1) P. S. Bimbra, "Generalized Theory of Electrical Machines", 5^{th} Edition, Khanna Publications, 1995

2) R. Krishnan, "Electric Motor Drives - Modeling, Analysis & Control", PHI Learning Private Ltd, 2009

3) P. C. Krause, Oleg Wasynczuk, Scott D. Sudhoff, "Analysis of Electrical Machinery and Drive Systems", 2^{nd}Edition, Wiley (India), 2010

4) Arthur R Bergen and Vijay Vittal, "Power System Analysis", 2^{nd} Edition, Pearson, 2009

5) Prabha Kundur, "Power System Stability and Control", TMH, 2010

6) Chee-Mun Ong, "Dynamic Simulation of Electric Machinery using Matlab/ Simulink", Prentice H

18PEPSE130	Power Quality Issues and Mitigation Techniques	(4-0-0)4

Contact Hours: 52

Course Learning Objectives (CLOs):

1. The basic concept of power quality phenomenon occurring in a power system.
2. The causes of power quality phenomena and their effects
3. Behavior of electronics devices, variable speed ac/dc drives and power system components due to power quality phenomenon
4. The performance evaluation of power system and analysis methods
5. Mitigation of power quality phenomenon in power system

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		Mapping to POs(1 to 4)		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO1	Explain the basic concept of power quality phenomenon occurring in a power system	1	3	2
CO2	Comprehend behavior of electronics devices, variable speed ac/dc drives and power system components due to power quality phenomenon	3, 4		2
CO3	Analyze performance of power system using different analysis methods	4	3	2
CO4	Compare different methods of mitigation of power quality phenomenon in power system	1	3	2

POs	PO-1	PO-2	PO-3	PO-4
Mapping Level	3	1	2.25	3

Prerequisites: Basics of power quality issues

Contents:

I. Introduction:

Introduction to power quality, overview of power quality phenomena, power quality and EMC standard. **04 Hrs.**

II. Long Interruptions and Reliability Evaluation:

Introduction, observation of system performance, standards and regulations, overview of reliability evaluation, reliability evaluation techniques, cost of interruptions, comparison of observation and reliability evaluation, examples.

08 Hrs.

III. Short Interruptions:

Introduction, terminology, origin of short interruptions, monitoring of short interruptions, influence on equipment, single phase tripping, stochastic prediction of short interruptions. **08 Hrs.**

IV. Voltage Sags - Characterization:

Introduction, voltage sag magnitude, voltage sag duration, three phase unbalance, phase angle jumps, magnitude and phase angle jumps for three phase unbalanced sags, other characteristic of voltage sags, load influence on voltage sags, sag due to starting of induction motors. **08 Hrs.**

V. Voltage Sags – Equipment Behavior:

Introduction, computers and consumer electronics, adjustable speed AC drives, adjustable speed DC drives, other sensitive load. **08 Hrs**.

VI. Voltage Sags – Stochastic Assessment:

Compatibility between equipment and supply, voltage sag coordination chart, power quality monitoring, method of fault positions, method of critical distances. **08 Hrs.**

VII. Mitigation of Interruptions and Voltage Sags:

Overview of mitigation methods, power system design – redundancy through switching and parallel operation, system equipment interface. **08 Hrs.**

Reference Books:

1) Math H J Bollen, “Understanding Power Quality Problems; Voltage Sags and Interruptions”, Wiley India, 2011.

2) Roger C Dugan, et.el, “Electrical Power Systems Quality”, 3rd Edition, TMH, 2012.

3) G. T. Heydt, “Electric Power Quality”, Stars in a Circle Publication, 1991.

4) Ewald F Fuchs, et.el, “Power Quality in Power System and Electrical Machines”, Academic Press, Elsevier, 2009.

18PEPSL101	Power System Laboratory – I	(0-0-3) 2

Contact Hours: 36

Course Learning Objectives (CLOs):

1. Conduct of experiment for operator request power flow analysis, contingency analysis and ranking for an interconnected power system
2. Conduct of experiment to obtain PV & QV curve for a given power system for voltage stability analysis
3. Conduct of experiments for fault analysis including different configurations of transformers in power system
4. Conduction of experiments for relay coordination and capacitor bank switching to control overvoltage and inrush current
5. Conduction of experiments for vacuum circuit breaker current chopping, electromagnetic analysis during charging of a long transmission line, Lightning impulse model, surge arrester model, CT and CVT transient model analysis

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1 to 4)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO1	Apply the knowledge of electrical engineering in conducting different experiment in the laboratory.	4	1, 3	2
CO2	Use suitable simulation software package for the conduction of experiments and analyze the results.	4	1, 3	2

POs	**PO-1**	**PO-2**	**PO-3**	**PO-4**
Mapping Level	2	1	2	3

Prerequisites: Power System Analysis

List of Experiments

1. Operator request load flow using voltage and frequency dependent load modeling and generator droop characteristic.
2. Contingency analysis and Ranking for a given inter connected power system having minimum ten buses and ten series elements.
3. Obtaining of PV & PQ curve for a given power system with load buses and voltage instability analysis
4. Sequence impedance diagram development and distribution of earth fault current computation in a practical power system having auto transformers with tertiary delta winding, star-delta and delta-star configurations.
5. Over current relay co-ordination with and without instantaneous setting for a given network with NI relay characteristic curves.
6. Capacitor bank switching studies and control of over voltage and inrush current.
7. Electromagnetic transient analysis during charging of a 400 kV, 300 km long line (i) without pre-insertion resistance (ii) With pre-insertion resistance (iii) With shunt reactor at the receiving end of the line.
8. Vacuum circuit breaker current chopping phenomenon and suppression of over voltage using (i) Surge arrestor (ii) R-C network.
9. Lightning impulse model and surge arrestor modeling studies using electromagnetic transient analysis for a given transmission line.
10. CT and CVT transients modeling using electromagnetic transient analysis.

18PEPSL102	**Seminar**	**(0-0-2)1**

Contact Hours: 36

Course Learning Objectives (CLOs):

The objective of the seminar is to inculcate self-learning, enhance communication skill, involve in group discussion and present the ideas before the audience.

Each student, under the guidance of a Faculty, is required to

i) Choose a topic of his/her interest relevant to the Course of Specialization

ii) Carryout literature survey, organize the subject topics in a systematic order

iii) Prepare the report with own sentences

iv) Type the matter to acquaint with the use of Micro-soft equation and drawing tools or any such facilities

v) Present the seminar topic at least for 30 minutes through power point slides

vi) Answer the queries and involve in debate/discussion lasting for about 10 minutes

vii) Submit two copies of the typed report with a list of references

The participants shall take part in discussion to foster friendly and stimulating environment in which the students are motivated to reach high standards and become self-confident. The internal assessment marks shall be awarded by a committee consisting of at least two staff members based on the relevance of the topic, presentation skill, participation in the question & answer session and quality of report.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1 to 4)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO1	Communicate effectively on a technical topic	1, 3	2	4
CO2	Learn new technical things by self-study	1, 3	2	4
CO3	Involve in technical group discussion actively	1, 3	2	4
CO4	Face and interact with class audience	1, 3	2	4

POs	**PO-1**	**PO-2**	**PO-3**	**PO-4**
Mapping Level	3	2	3	1

II - Semester M. Tech. (Power Systems Engineering)

18PEPSC200 Economic Operation & Control of Power System (4-0-0) 4

Contact Hours: 52

Course Learning Objectives (CLOs):

1. To provide students the knowledge of optimization techniques used in the power system and Load Frequency Control (LFC).
2. To provide a solid foundation in mathematical and engineering fundamentals required to control the governing system in Turbine models.
3. To provide the knowledge of Hydrothermal scheduling, reactive power control

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		Mapping to POs(1 to 4)		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO1	Discuss about thermal and hydro power plants operation in meeting the load demand optimally.		2	3
CO2	Demonstrate the importance of reactive power control.	1	2, 3	
CO3	Model single area load frequency control and two area load frequency control	2	1	3, 4
CO4	Model and design turbine and Automatic controller.	2	1	3, 4

POs	**PO-1**	**PO-2**	**PO-3**	**PO-4**
Mapping Level	2.33	2.5	1.25	1

Prerequisites: Power System Analysis

Contents:

I. Introduction:

Different states of power systems, energy control centers, power systems control problems, steady state & transient security of power systems, security monitoring, SCADA systems, Automatic generation and voltage control. **08 Hrs**.

II. Power System Security:

Introduction, factors affecting system security, power system contingency analysis, and detection of network problems. Network sensitivity methods, calculation of network sensitivity factor, connecting generator dispatch by sensitivity methods, contingency ranking. **08 Hrs**.

III. Control of Voltage and Reactive Power:

Introduction, generation and absorption of reactive power, relation between voltage, power and reactive power at a node-single machine infinity bus system, methods of voltage Control. **08 Hrs**.

IV. Power System Optimization:

Optimal system operation with thermal plants, incremental production costs for steam power plants, analytical form of generation costs of thermal power plants, constraints in economic operation flowchart. Transmission loss equation for B co-efficient, unit commitment: statement of the problem, constraints, spinning reserve. **08 Hrs**.

V. Loss Co-efficient :

Definitions and Computation of loss co-efficient, incremental transmission of transmission loss, loss co-efficient using Y Bus, sparse matrix techniques, use of load flow Jacobian for economic dispatch- flowchart -AGC -AGL - use of AGE for economic dispatch, block diagram, block- merit order scheduling. **10 Hrs**.

VI. Hydrothermal Coordination :

Introduction, Hydroelectric Plant Models, Scheduling Problems, the Short-Term Hydrothermal Scheduling Problem, Short-Term Hydro-Scheduling: A Gradient Approach, Hydro-Units in Series (Hydraulically Coupled), Pumped-Storage Hydro plants, Dynamic-Programming Solution to the Hydrothermal Scheduling Problem, Hydro-Scheduling Using Linear Programming, Hydro-Scheduling with Storage Limitations. **10 Hrs**.

Reference Books:

1) C. L, Wadhwa, “Electrical Power System”, New Age International, 2010

2) Allen Wood and Woolenberg, “Power Generation Operation and Control”, Wiley India 2nd Edition, 2009.

3) Olle. I. Elgerd, “Electrical Energy Systems”, TMH, 2001

4) C. L. Kusic “Computer Aided Power System Analysis”, CRC Press, 2nd Edition Second Indian reprint, 2014

5) Nagrath & Kothari, “Modern Power System Analysis”, 4th Edition, TMH, 2011

18PEPSC201	Distribution System Design & Control	(4-0-0) 4

Contact Hours: 52

Course Learning Objectives (CLOs):

1. To explain the principles of design and operation of electric distribution system.
2. To apply analytic techniques pertaining to primary distribution systems.
3. To use basic design principles for distribution substations and facilities.
4. To examine primary distribution systems with capacitor compensation.
5. To obtain the reliability indices related to the distribution system.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		Mapping to POs(1 to 4)		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO1	Design, Develop and Analyze primary and secondary distribution systems.	1	3	2
CO2	Evaluate and suggest suitable power factor correction capacitors in the system.	1	3	2
CO3	Develop reliability model and obtain reliability indices.	1	3, 4	2

POs	**PO-1**	**PO-2**	**PO-3**	**PO-4**
Mapping Level	3	1	2	2

Prerequisites:

Contents:

I. Distribution System Planning & Automation:

Introduction, distribution system planning; factors affecting system planning, present technique, role of computers in distribution planning. **05 Hrs.**

II. Distribution Substation:

Introduction, load characteristics, relationship between loss and load factor, maximum diversified demand, Load management. Substation location, rating a distribution substation, substation services area with 'n' primary feeders, comparison of four and six feeder patterns, derivation of K constant, substation application curves, present voltage drop formula. **12 Hrs.**

III. Primary and Secondary Distribution Systems:

Introduction, feeder types and voltage levels, feeder loading rectangular type development, radial type development application of the A, B, C, D general circuit constants to radial feeders, secondary banking. **10 Hrs.**

IV. Voltage Drop and Power Loss Calculations:

Three phase balanced primary lines, single phase lines, Four-Wire multi grounded Common Neutral system, Methods to analyze Distribution Cost.

07 Hrs.

V. Application of Capacitors in Distribution Systems:

Introduction, Power capacitors series and shunt power factor correction, economic power factor, applications of capacitors and installation, types of control, economic justification, practical procedure to determine the best location, mathematical procedure for optimum- allocation, dynamic behavior of distribution system. **08 Hrs.**

VI. Distribution System Reliability:

Introduction, basic reliability concepts, series, parallel and series-parallel systems, Markov Processes, Distribution Reliability Indices: Sustained, Momentary, Load and Energy based indices, Usage of indices, Benefits of Reliability Modeling in system performance. **10 Hrs.**

Reference Books:

1) Turan Gonen, "Electric Power Distribution System Engineering", 2nd Edition, BSP Books Pvt. Ltd, 2010.

2) A. S. Pabla, "Electric Power Distribution System", 6th Edition, TMH, 2011.

3) Gorti Ramamurthy, "Hand Book of Electrical Power Distribution", University Press, 2nd Edition, 2009.

18PEPSE225	**Reactive Power Management in Power System**	**(4-0-0) 4**

Contact Hours: 52

Course Learning Objectives (CLOs):

1. To identify the necessity of reactive power compensation
2. To describe load compensation and reactive power control
3. To select various types of reactive power compensation in transmission systems
4. To differentiate the static and dynamic compensation
5. To characterize utility practices and reactive power management.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1 to 4)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO1	Demonstrate knowledge on: Load Compensation and different methods of reactive power control in transmission system	1	3	2
CO2	Observe dynamic performance of transmission system with compensation	1	3	2
CO3	Demonstrate knowledge on: static and dynamic compensation, sources of harmonics and reactive power coordination between utility and consumers	1, 4	3	2

POs	**PO-1**	**PO-2**	**PO-3**	**PO-4**
Mapping Level	3	1	2	3

Prerequisites: Power system analysis

Contents:

I. Theory of Load Compensation:

Introduction- Requirement for compensation, objectives in load compensation, the ideal compensator specifications of a load compensator, power factor correction and voltage regulations in single phase system, phase balancing and power factor correction of unsymmetrical loads, compensation in terms of symmetrical components expression for the compensating susceptance in terms of phase line currents. **12 Hrs.**

II. Reactive Power Control:

Fundamental requirement in AC power transmission, fundamental transmission line equation, surge impedance and natural loading, voltage and current profiles of uncompensated radial and symmetrical line on open circuit, uncompensated line under load, effect of line length, load power and p. f on voltage and reactive power, passive and active compensators, uniformly distributed fixed compensation, passive shunt compensation, control of open circuit voltage by shunt reactance, required reactance of shunt reactors, multiple shunt reactors along the line, voltage control by means of switch shunt compensation, midpoint shunt reactor or capacitor, expression for mid-point voltage, series compensation , objectives and practical limitation , symmetrical line with midpoint series capacitor and shunt reactor, power transfer characteristics and maximum transmissible power for a general case, fundamental concepts of compensation by sectioning. **24 Hrs.**

III. Dynamic Performance of Transmission Systems with Reactive Power Compensation:

The dynamics of electrical power system. Need for adjustable reactive compensation and four characteristics time period. **04 Hrs.**

IV. Principles of Static Compensation:

Principle of operation of thyristor controlled reactor, thyristor switch capacitor, saturated reactor compensator. **03 Hrs.**

V. Series Capacitors:

Introduction, protective gear, reinsertion schemes and varistor protective gear. **03 Hrs**.

VI. Synchronous Condenser:

Introduction, power system voltage control, emergency reactive power supply, starting methods for motor, reduced voltage starting, static starting. **02 Hrs.**

VII. Harmonics:

Sources, effects of harmonics on electrical equipment. **02 Hrs.**

VIII. Reactive Power Co-Ordination:

Reactive power management, utility objectives and utility practices, transmission benefits. **02 Hrs.**

Reference Books:

1) T. J. E Miller, "Reactive Power Control in Electrical Systems", BSP books PVT Ltd, 2010.

2) D. Tagare, "Reactive Power Management", TMH, 2011.

3) A. Chakrabarti, D. P Kothari, A. K Mukhopadhyay and D. E Abinandan, "An Introduction to Reactive Power Control and Voltage Stability in Power Transmission Systems", PHI, 2010.

4) George J. Wakileh, "Power Systems Harmonics; Fundamentals, Analysis and Filter Design", Spinger, 2014.

18PEPSE226 Artificial Intelligence Techniques To Power System (4-0-0) 4

Contact Hours: 52

Course Learning Objectives (CLOs):

1. To impart knowledge on basic concepts of AI, soft and hard computing.
2. To explain the concepts of artificial intelligence, fuzzy logic and genetic algorithms.
3 To apply the AI techniques to power system applications.

Course Outcomes:

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs (1 to 4)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Differentiate between Soft Computing and hard Computing techniques	1	3	2
CO-2	Study concepts of artificial neural networks, fuzzy logic and genetic algorithms	4	1,3	2
CO-3	Apply appropriate AI framework for solving power system problems	4	3	2

PO's	**PO-1**	**PO-2**	**PO-3**	**PO-4**
Mapping Level	2.67	2.67	2.33	1.00

Contents:

I. Introduction

Introduction, definition of AI, difference between soft computing techniques and hard computing systems, Expert Systems, brief history of ANN, Fuzzy Logic and Genetic Algorithm. **06 Hrs.**

II. Artificial Neural Networks

Introduction Models of Neuron Network, Architectures , Knowledge representation, Neural networks–Learning, Multi – layer perceptron using Back propagation Algorithm (BPA) , Self-Organizing Map (SOM) , Radial Basis Function Network , Functional Link Network (FLN). **14 Hrs.**

III. Fuzzy Logic

Introduction, Fuzzy versus crisp, Fuzzy sets, Membership function, Basic Fuzzy set operations, Properties of Fuzzy sets , Fuzzy Cartesian Product , operations on Fuzzy relations ,Fuzzy-logic, Fuzzy Quantifiers, Fuzzy Inference Fuzzy Rule based system, De-fuzzification methods. **10 Hrs.**

IV. Genetic Algorithms

Introduction, Encoding, Fitness Function, Reproduction operators, Genetic Modeling, Genetic operators, Cross over, Single site cross over, Two point cross over, Multi point cross over, Uniform cross over, Matrix cross over, Cross over Rate , Inversion & Deletion , Mutation operator, Mutation , Mutation Rate, Bit–wise operators , Generational cycle , convergence of Genetic Algorithm

10 Hrs.

V. Applications of AI Techniques

Load forecasting , Load flow studies , Economic load dispatch , Load frequency control , Single area system and two area system , Small Signal Stability (Dynamic stability) Reactive power control , speed control of DC and AC Motors. **12 Hrs.**

Reference Books:

1) S. Rajasekaran and G. A. V. Pai Neural Networks, Fuzzy Logic & Genetic Algorithms, PHI, New Delhi, 2003.

2) Rober J. Schalkoff, Artificial Neural Networks, Tata McGraw Hill Edition, 2011

3) Kevin Warwick, Arthur Ekwue, Raj Aggarwal, Artificial Intelligence Techniques in Power Systems.

18PEPSE227	**Power System SCADA**	**(4-0-0) 4**

Contact Hours: 52

Course Learning Objectives (CLOs):

The advent in digital technology has led paradigm shift in the control strategies of various engineering systems. The operation of integrated power system is challenge posed to the control engineers. The technology usage happened in incremental fashion and hence, it is necessary to integrate these in phase wise manner. The information and communication technology is useful for real time operation of critical infrastructures. The initiation is with data acquisition and supervisory control in segmented approach. This subject makes the students to understand the methods of data acquisition, transmission in open loop manner & closed loop manner, use of ICT, communication protocols, presentation of data, processing of data and generating control signals etc. Further it provides information regarding the information management system and security measures. The students also learn the codes specified by the standard organizations.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1 to 4)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Recite the concept of power system state estimation techniques, metering, measurements, operation and control.		1	3
CO-2	Comprehend the importance of automation in critical infrastructures and basics of SCADA system as applied to power systems.		1	3
CO-3	Use communication protocols for data transmission in closed and open loop environment, vulnerability, security, IDS and security projects adhering to standard & reference documents.	1	2	3
CO-4	Explain the requirements for substation, distribution station and feeder automation with protective and alarming schemes.	1	4	3

POs	**PO-1**	**PO-2**	**PO-3**	**PO-4**
Mapping Level	**2.5**	**2.0**	**1.0**	**2.0**

Prerequisites: 1.Power System Analysis
2. Power System Operation and Control

Contents:

I. State Estimation in Energy Control Centers (ECC):

Introduction, power system measurements, states of power systems, overview of different state estimator techniques, bad data handling, pseudo measurements, and observability analysis. **05 Hrs.**

II. SCADA System:

History of Critical Infrastructure Directives, SCADA system evolution, definitions, SCADA system architecture, SCADA applications, SCADA system security issues, overview, SCADA system desirable properties, SCADA systems in the critical infrastructure, employment of SCADA systems.

OSI and TCP/IP reference models. Few examples of SCADA controlled systems. **08 Hrs.**

III. Evolution of SCADA Protocols:

Background technologies of the SCADA protocols, SCADA protocols (the MODBUS model, the DNP3 protocols, UCA 2.0 and IE61850 standards, control area network, control and information protocol, device Net, control Net, Ether Net/IP, FFB, profibus, the security implications of the SCADA protocols, demilitarized zone. **08 Hrs.**

IV SCADA Vulnerabilities and Attacks:

The myth of SCADA invulnerability, SCADA risk components, risk management components, assessing the risk, mitigating the risk, SCADA threats and attack routes, SCADA Honey net project. **08 Hrs.**

V. SCADA Security Methods & Techniques:

SCADA security mechanisms, SCADA intrusion detection systems, SCADA security standards and reference documents, standards and reference documents. **05 Hrs.**

VI. Power System Automation:

Introduction, overview of power system instrumentation, power system metering, Power plant automation, substation automation, transmission management, distribution management, SCADA distribution management, distribution automation – feeder automation, demand side management, load management. **08 Hrs.**

VII. Substation Automation and Protocol Standards for Power Systems:

Need for a automation, definition of integration and automation, substation control panels – with electromechanical devices, with Intelligent Electronic Devices (IED), automatic load restoration – intelligent bus fail to vAr, supply, line sectionalizing, monitoring of equipment condition, alarm processing, power quality, switched feeder capacitor banks, equipment rating. Integrated protection functions – Adaptive relaying. **08 Hrs.**

Reference Books:

1) Krutz, Ronald. L, “Securing SCADA Systems”, 2nd Edition, Wiley, 2005.

2) Michael Wiebe, “A Guide to Utility Automation: A MR, SCADA, and It Systems for Electric Power”, Penn Well Books, 1999

3) Allen Wood &Woolenberg, “Power generation, operation and control” John Wiley Edition, 2012

4) Prabha K, “Power System Stability and Control” McGraw hill, 2016

18PEPSE228	HVDC Power Transmission	(4-0-0) 4

Contact Hours: 52

Course Learning Objectives (CLOs):

1. To give an exposure to the new technology domain "HVDC Power Transmission".
2. To impart the basic knowledge regarding the HVDC Power Transmission.

Course Outcomes (Cos):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1 to 4)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Know about the advantages and the relevance of HVDC Power Transmission.	1		
CO-2	Know about the applications and present status of HVDC Power Transmission.	1		
CO-3	Know about the role of Power Electronics in HVDC Power Transmission. They learn about the different types of converters employed, the firing aspects, etc.	1	2	
CO-4	Know about the different control aspects of HVDC Power Transmission. The students will know about the filters, measurement, monitoring aspects with reference to HVDC Power Transmission.	1	2	
CO-5	Will know about the filters, measurement, monitoring aspects with reference to HVDC Power Transmission.	1		
CO-6	Know about the present technology trends in HVDC Power Transmission.	1	2	

POs	**PO-1**	**PO-2**	**PO-3**	**PO-4**
Mapping Level	**3.0**	**2.0**		

Pre Requisites: Basics of Electrical Engineering, Power Electronics and Power Systems

Contents:

I. HVDC Transmission: Introduction; Comparison of AC-DC Transmission: Evaluation of Transmission Cost, Technical Consideration, Reliability and Availability Costs; Applications of dc Transmission; Types of HVDC Systems: Monopolar Link, Bipolar Link, Homopolar Link. **04 Hrs**.

II. Types of Converters: Introduction; Current Source Converters (CSC): Case with no overlap period, Case with overlap period less than 60 degrees; Voltage Source Converters (VSC): Control of the DC Capacitor Voltage, VSC with AC Current Control, VSC with AC Voltage Control. **08 Hrs.**

III. Synchronization Techniques for Power Converters: Introduction; Review of GFUs: Individual Phase Control (IPC) Unit, Equi-Distant Pulse Control (EPC) Unit; GFUs: Conventional GFU, DQO GFU, Comparison. **06 Hrs**.

IV.HVDC Controls: Historical Background; Functions of HVDC Controls; HVDC and FACTS Controllers; Control Basics for a Two-terminal DC Link; Current Margin Control Method: Rectifier Mode of Operation, Inverter Mode of Operation; Current Control at the Rectifier; Inverter Extinction Angle Control; Hierarchy of Controls. **08 Hrs**.

V. Forced Commutated HVDC Converters: Introduction; Commutation Techniques for HVDC Converters; Examples of FC Converters for HVDC Transmission: Circuit Commutated Converters, Self-Commutated Converters. **04 Hrs.**

VI. Capacitor Commutated Converters for HVDC Systems: Introduction; Reactive Power Management; Thyristor Valve Modules. **04 Hrs.**

VII. HVDC Systems Using Voltage Source Converters: Introduction; Basic Elements of HVDC using VSCs - Voltage Source Converters; Voltage Source Converter - Operating Principles of a VSC. **06 Hrs.**

VIII. Active Filters: Introduction; DC Filters; AC Filters. **04 Hrs.**

IX. Measurement/Monitoring Aspects: Introduction; Monitoring of Signals Protection against Over-currents; Protection against Over-voltages. **04 Hrs.**

X. Modern HVDC - State Of The Art: Introduction; Past Decade Version; Present Decade Version. **04 Hrs.**

Reference Books:

1) Vijay K Sood, “HVDC and FACTs Controllers; Applications of Static Converters in Power Systems, BSP Books Pvt Ltd, First Indian reprint 2013.

2) K. R. Padiyar, “HVDC Power Transmission Systems”, New Age International, 2012.

3) E. W. Kimbark “Direct Current Transmission”, Vol.1, Wiley Inter-Science, London, 2006.

4) Arrilaga, “High Voltage Direct Current Transmission”, The Institute of Engineering and Technology, 2ndEdition, 2007.

5) S Kamakshaiah and V Kamaraju, “HVDC Transmission”, TMH, 2011.

18PEPSE229	Fundamentals of Smart Grid Technology	(4-0-0) 4

Contact Hours: 52

Course Learning Objectives (CLOs):

The use of communications and information technologies is likely to cause major shifts in the way energy gets delivered. The smart grid will use these technologies to deliver electricity reliably and efficiently, and it has the potential to radically change the electricity sector in the same way that new technologies changed the telecommunications sector. Students in this course will learn the fundamentals of the smart grid: its purpose and objectives, its technologies, its architectures, and its management. Students will also learn many of the challenges facing the smart grid as part of its evolution.

Course Outcomes (Cos):

Description of the Course Outcome: At the end of the course the student will be able to:		Mapping to POs (1 to 4)		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Recite the various aspects of the smart grid	1	3	2
CO-2	Demonstrate how a perfect power system can be realized	1	3	2
CO-3	Analyse the power system in real time with enabling technologies	4	3	2
CO-4	Use technology alternatives for efficient electricity end use.	4	3	2

PO's	PO-1	PO-2	PO-3	PO-4
Mapping Level	2.5	2.0	1.5	1.5

Prerequisites: 1. Renewable Energy Sources 2. Transmission and Distribution (AC/DC)

Contents:

I. Introduction

Introduction to smart grid, electricity network, local energy networks, electric transportation, low carbon central generation, attributes of the smart grid, alternate views of a smart grid. **04 Hrs.**

II. Smart Grid to Evolve a Perfect Power System

Introduction, overview of the perfect power system configurations, device level power system, building integrated power systems, distributed power systems, fully integrated power system, nodes of innovation. **06 Hrs.**

III DC Distribution and Smart Grid

AC Vs. DC sources, benefits of and drives of dc power delivery systems, powering equipment and appliances with DC, data centers and information technology loads, future neighborhood, potential future work and research.

04 Hrs.

IV. Intelligent grid Architecture for the Smart Grid:

Introduction, launching intelli-grid, intelli-grid today, smart grid vision based on the intelli-grid architecture, barriers and enabling technologies. **06 Hrs.**

V. Dynamic Energy Systems Concept

Smart energy efficient end use devices, smart distributed energy resources, advanced whole building control systems, integrated communications architecture, energy management, role of technology in demand response, current limitations to dynamic energy management, distributed energy resources, overview of a dynamic energy management, key characteristics of smart devices, key characteristics of advanced whole building control systems, key characteristics of dynamic energy management system. **08 Hrs**.

VI. Energy Port as Part of the Smart Grid

Concept of energy -port, generic features of the energy port. Policies and Programs to Encourage End – Use Energy Efficiency: Polices and programs in action; multinational, national, state, city and corporate levels. **08 Hrs**.

VII. Market Implementation

Framework, factors influencing customer acceptance and response, program planning, monitoring and evaluation. **06 Hrs.**

VIII. Efficient Electric End – Use Technology Alternatives

Existing technologies, lighting, space conditioning, indoor air quality, domestic water heating, hyper efficient appliances, ductless residential heat pumps and air conditioners, variable refrigerant flow air conditioning, heat pump water heating, hyper efficient residential appliances, data center energy efficiency, LED street and area lighting, industrial motors and drives, equipment retrofit and replacement, process heating, cogeneration, thermal energy storage, industrial energy management programs, manufacturing process, electro - technologies, residential, commercial and industrial sectors. **10 Hrs.**

Reference Books:

1) Clark W Gellings, “The Smart Grid, Enabling Energy Efficiency and Demand Side Response”, CRC Press, 2009.

2) Janaka Ekanayake, Kithsiri Liyanage, Jianzhong. Wu, Akihiko Yokoyama, Nick Jenkins, “Smart Grid: Technology and Applications”, Wiley, 2012.

3) James Momoh, “Smart Grid: Fundamentals of Design and Analysis”, Wiley, IEEE Press,

18PEPSE230	Distributed Generation and Micro Grids	(4-0-0) 4

Contact Hours: 52

Course Learning Objectives (CLOs):

1. To illustrate the concept of distributed generation
2. To analyze the impact of grid integration.
3. To study concept of Microgrid and its configuration
4. To study protection issues and communication protocols

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		Mapping to POs (1 to 4)		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Review the conventional power generation	1	3	2
CO-2	Analyze the concept of distributed generation and installation	1	3	2
CO-3	Design the grid integration system with conventional and non-conventional energy sources	4	3	2
CO-4	Design the dc and ac micro grid, Analyze power quality issues, control operation	4	3	2
CO-5	Understand protection concepts and communication protocols in Microgrids	4	3	2

PO's	**PO-1**	**PO-2**	**PO-3**	**PO-4**
Mapping Level	**3**	**2.6**	**3**	**2**

Prerequisites: AC Generation, Transmission and Distribution

Contents:

I. INTRODUCTION:

Conventional power generation: advantages and disadvantages, Energy crises, Non - conventional energy (NCE) resources: review of Solar PV, Wind Energy systems, Fuel Cells, micro-turbines, biomass, and tidal sources. **08 Hrs.**

II.DISTRIBUTED GENERATIONS (DG):

Concept of distributed generations, topologies, selection of sources, regulatory standards/ framework, Standards for interconnecting Distributed resources to electric power systems: IEEE 1547. DG installation classes, security issues in

DG implementations. Energy storage elements: Batteries, ultra-capacitors, flywheels. Captive power plants. **10 Hrs.**

III. IMPACT OF GRID INTEGRATION:

Requirements for grid interconnection, limits on operational parameters, voltage, frequency, THD, response to grid abnormal operating conditions, islanding issues. Impact of grid integration with NCE sources on existing power system: reliability, stability and power quality issues. **08 Hrs.**

IV. BASICS OF A MICROGRID:

Concept and definition of microgrid, microgrid drivers and benefits, review of sources of microgrids, typical structure and configuration of a micro grid, AC and DC microgrids, Power Electronics interfaces in DC and AC micro grids.

08 Hrs.

V. CONTROL AND OPERATION OF MICROGRID:

Modes of operation and control of microgrid: grid connected and islanded mode, Active and reactive power control, protection issues, anti-islanding schemes: passive, active and communication based techniques, microgrid communication infrastructure, Power quality issues in microgrids, regulatory standards, Microgrid economics, Introduction to smart microgrids. **10 Hrs.**

VI. PROTECTION ISSUES FOR MICROGRIDS:

Introduction, Islanding, Different islanding scenarios, Major protection issues of stand-alone Microgrid - Impact of DG integration on electricity market, environment, distribution system, communication standards and protocols.

10 Hrs.

Reference Books:

1) Amirnaser Yezdani, and Reza Iravani, "Voltage Source Converters in Power Systems: Modeling, Control and Applications", IEEE John Wiley Publications, 2009.
2) Dorin Neacsu, "Power Switching Converters: Medium and High Power", CRC Press, Taylor & Francis, 2006.
3) Chetan Singh Solanki, "Solar Photo Voltaics", PHI learning Pvt. Ltd., New Delhi, 2009
4) J. F. Manwell, J. G "Wind Energy Explained, Theory Design and Applications,". McGowan Wiley publication, 2nd Edition, 2009.
5) D. D. Hall and R. P. Grover, "Biomass Regenerable Energy", John Wiley, New York, 1987.
6) John Twidell and Tony Weir, "Renewable Energy Resources", Taylor and Francis Publications, Second Edition, 2006.
7) S. Chowdhury, S.P. Chowdhury and P. Crossley, Microgrids and Active Distribution Networks, ISBN 978-1-84919-014-5, IET, 2009.

18PEPSL202	Power System Laboratory-II	(0-0-3)2

Contact Hours: 36

Course Learning Objectives (CLOs) is to:

1. Conduct of experiment for reactive power optimization and loss minimization studies.
2. Conduct of experiment for Dynamic VAR compensation and voltage control using shunt SVC
3. Conduct of experiments for economic dispatch problem considering network loading constraints and computation of bus incremental cost.
4. To model a power system and perform transient stability and small signal stability studies
5. To model automatic voltage regulator and governor to study their effect on stability
6. To conduct Frequency and voltage dependency model of the load and under frequency load shedding
7. Conduct of experiment for ATC computation, open access feasibility study
8. Conduct of experiment for observability analysis, state estimation and bad data detection
9. Conduct of experiment for Harmonic analysis and voltage and current harmonic distortion computation for a given power system. Tuned filter design to eliminate the harmonic currents.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs (1 to 4)** Substantial Level (3)	Moderate Level (2)	Slight Level (1)
CO-1	Apply the knowledge of electrical engineering in conducting different experiment in the laboratory.	1	3	2
CO-2	Use suitable simulation software package for the conduction of experiments and analyze the results.	1, 4	3	2
CO-3	Model a power system to perform transient stability and small signal stability studies.	1, 4	3	2
CO-4	Model automatic voltage regulator and governor to study their effect on stability	1, 4	3	2
CO-5	Explain Reactive Power Optimization, Dynamic VAR Compensation, Economic Dispatch, ATC, Observably, State Estimation, Bad data detection and Harmonic Analysis	1, 4	3	2

POs	PO-1	PO-2	PO-3	PO-4
Mapping Level	3	1	2	3

<u>List of Experiments</u>

1. Reactive power optimization and loss minimization studies for a given power system.
2. Dynamic VAR compensation and voltage control using shunt SVC.
3. Economic dispatch problem taking into account the network loading constraints and computation of bus incremental cost.
4. Transient stability studies for a given system having minimum 10 buses, machines and an infinite grid to determine (i) Critical clearing time (ii) Natural frequency of oscillations of electro-mechanical system considering classical representation of the machine and detailed modeling (sub-transient model) of the machine.
5. The AVR and Governor modeling and their effect on system stability.
6. Frequency and voltage dependency model of the load and under frequency load shedding.
7. Eigen value computation and small signal stability studies for a given power system with at least 3 machines and 10 buses using IEEE-Type 1 AVR and turbine-governor models.
8. ATC computation and open access feasibility studies for the given power system network
9. Observability analysis, state estimation and bad data detection for a given power system using measurement data.
10. Harmonic analysis of voltage and current harmonic distortion computation for a given power system. Tuned filter design to eliminate the harmonic currents.

*** Software MI POWER / MATLAB will be used**

18PEPSL203	Seminar	(0-0-3) 3

Contact Hours: 36

Course Learning Objectives (CLOs):

The objective of the seminar is to inculcate self-learning, face audience confidently, enhance communication skill, involve in group discussion and present and exchange ideas.

Each student, under the guidance of a Faculty, is required to

1. Choose, preferably, a recent topic of his/her interest relevant to the Course of Specialization.
2. Carryout literature survey, organize the course topics in a systematic order.
3. Prepare the report with own sentences.
4. Type the matter to acquaint with the use of Micro-soft equation and drawing tools or any such facilities.
5. Present the seminar topic orally and/or through power point slides.
6. Answer the queries and involve in debate/discussion.
7. Submit two copies of the typed report with a list of references.

The participants shall take part in discussion to foster friendly and stimulating environment in which the students are motivated to reach high standards and become self-confident.

The Internal Assessment marks for the seminar shall be awarded (based on the relevance of the topic, presentation skill, participation in the question and answer session and quality of report) by the committee constituted for the purpose by the Head of the Department. The committee shall consist of two faculties from the department with the senior most acting as the Chairman.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs (1 to 4)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Communicate effectively on a technical topic	1, 3	2	4
CO-2	Learn new technical things by self-study	1, 3	2	4
CO-3	Involve in technical group discussion actively	1, 3	2	4
CO-4	Face and interact with class audience	1, 3	2	4

POs	**PO-1**	**PO-2**	**PO-3**	**PO-4**
Mapping Level	3	2.0	3	1.0