ACADEMIC REGULATIONS & COURSE STRUCTURE

For

CONTROL SYSTEMS (CS)
CONTROL ENGINEERING (CE)

(Applicable for batches admitted from 2016-2017)

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY: KAKINADA
KAKINADA - 533 003, Andhra Pradesh, India

I Semester

S. No.	Subject	L	P	Credits
1	Advanced Control Theory	4	--	3
2	Advanced Digital Control Systems	4	--	3
3	Stochastic Estimation and Control	4	--	3
4	System and Parameter Identification	4	--	3
5	**Elective-I** i. Computer Controlled Systems ii. Control of Special Machines	4	--	3
6	**Elective-II** i. Micro Controllers& Applications ii. Process Control and Automation	4	--	3
7	Simulation Laboratory	--	4	2
Total Credits				**20**

II Semester

S. No.	Subject	L	P	Credits
1	Robotics and Control	4	--	3
2	Non-Linear Systems Analysis	4	--	3
3	Digital Signal Processing	4	--	3
4	Optimal Control Theory	4	--	3
5	**Elective-III** i. A I Techniques ii. Embedded Real Time Operating System EMS	4	--	3
6	**Elective-IV** i. Decision and Estimation Theory ii. Embedded Computer Control.	4	--	3
7	Advanced Control System Laboratory	--	4	2
Total Credits				**20**

III Semester

S. No.	Subject	L	P	Credits
1	Comprehensive Viva-Voce	**--**	**--**	2
2	Seminar – I	--	--	2
3	Project Work Part - I	--	--	16
Total Credits				**20**

IV Semester

S. No.	Subject	L	P	Credits
1	Seminar – II	--	--	2
2	Project Work Part - II	--	--	18
Total Credits				**20**

I Year - I Semester	L	P	C
	4	0	3

ADVANCED CONTROL THEORY

(Common to CS & CE)

Course Educational Objectives:

- To present state models in various forms.
- To learn the concept of controllability and observability of LTI systems.
- To discuss and learn the design concepts for feedback controller and observers.

UNIT I

Introductory matrix algebra and linear vector space, State space representation of systems.Linearization of a non - linear system.Solution of state equations. Evaluation of State Transition Matrix (STM) - Simulation of state equation using MATLAB/ SIMULINK program.

UNIT II

Similarity transformation and invariance of system properties due to similarity transformations. Minimal realization of SISO, SIMO, MISO transfer functions. Discretization of a continuous time state space model.Conversion of state space model to transfer function model using Fadeeva algorithm.

UNIT III

Fundamental theorem of feedback control - Controllability and Controllable canonical form - Pole assignment by state feedback using Ackermann's formula – Eigen structure assignment problem. Observability and observable canonical form

UNIT IV

Linear Quadratic Regulator (LQR) problem and solution of algebraic Riccati equation using eigenvalue and eigen vector methods, iterative method. Controller design using output feedback.Internal stability of a system.Stability in the sense of Lyapunov, asymptotic stability of linear time invariant continuous and discrete time systems. Solution of Lyapunov type equation.

UNIT V

Duality between controllability and observability - Full order Observer based controller design. Reduced order observer design. Model decomposition and decoupling by state feedback. Disturbance rejection, sensitivity and complementary sensitivity functions. Design of full order observer using Ackermann's formula - Bass Gura algorithm.

Course Outcomes:

Aftercompletion ofthis coursethe students will be:

- Able to apply matrix algebra to develop various forms of state models.
- Able to develop and analyze physical systems.
- Able to analyze state models.
- Able to design state feedback controller and observer.

Reference Books:

1. K. Ogata, Modern Control Engineering, Prentice Hall, India 1997
2. T. Kailath, T., Linear Systems, Perntice Hall, Englewood Cliffs, NJ, 1980.
3. N. K. Sinha , Control Systems, New Age International, 3rd edition, 2005.
4. Panos J Antsaklis, and Anthony N. Michel, Linear Systems, New - age international (P) LTD. Publishers, 2009.
5. John J D'Azzo and C. H. Houpis , "Linear Control System Analysis and Design Conventional and Modern", McGraw - Hill Book Company, 1988.
6. B.N. Dutta, Numerical Methods for linear Control Systems - , Elsevier Publication, 2007.
7. C.T.Chen Linear System Theory and Design - PHI, India.
8. Richard C. Dorf and Robert H. Bishop, Modern Control Systems, 11th Edition, Pearson Edu, India, 2009.

I Year - I Semester

L	P	C
4	0	3

ADVANCED DIGITAL CONTROL SYSTEMS

(Common to CS & CE)

Course Educational Objectives:

- To familiarize mathematical analysis of digital control systems.
- To introduce state feedback controllers and observers for digital control systems.
- To understand state estimation and state observer design methodology of single output and multi output systems.

UNIT I

Overview of modern digital control theories, Z- and inverse Z-transformation and properties, Discrete-time systems and difference equations, Sampling and reconstruction (A/D and D/A conversions), Z- and S-plane correspondence and stability test, Analysis of sampled data systems.

UNIT II

Discrete-time state equations, Sampled continuous-time systems, Canonical forms, transformation to controllable, observable and diagonal forms, Controllability and observability.

UNIT III

State determination and control, State feedback and eigenvalue placement of single input systems, State feedback and eigenvalue placement of multi-Input systems, Quadratic optimal control, Digital tracking systems.

UNIT IV

State estimation, State observer design for single out-put systems, State observer design for multi-output systems, System Identification.

UNIT V

Digitizing analog controllers, Designing between-sample response, Digital hardware control, Actuators limitation.

Course Outcomes:

Aftercompletion ofthis coursethe students are able to:

- Analyze digital control theories using Z transform methods.
- Understand the stability criteria of discrete time systems.
- Obtain various state space models of discrete- time systems and verify controllability and observabilty.
- Design state observer for single output and multi output systems.
- Design digital hardware controller.

Reference Books:

1. Ms. Santina, A.R.Stuberud&G.H.Hostetter, Digital Control Systems Design, Oxford Univ Press, 2nd edition.
2. B.C Kuo, Digital Control Systems, 2nd Edition, Oxford Univ Press, Inc., 1992.
3. F. Franklin, J.D. Powell, and M.L. Workman, Digital control of Dynamic Systems, Addison - Wesley Longman, Inc., Menlo Park, CA , 1998.
4. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill, India, 1997.
5. C. H. Houpis and G.B. Lamont, Digital Control Systems, McGraw Hill, 1985.
6. John S. Baey, Fundamentals of Linear State Space Systems, Mc. Graw – Hill, 1st edition
7. Bernard Fried Land, Control System Design, Mc. Graw – Hill, 1st edition
8. Dorsay, Continuous and Discrete Control Systems, McGraw - Hill.

I Year - I Semester	L	P	C
	4	0	3

STOCHASTICESTIMATION AND CONTROL

(Common to CS & CE)

Course Educational Objectives:

- To formulate system models for continuous and discrete linear systems.
- To introduce the smooth estimation techniques for continuous and discrete linear systems.
- To understand various methods of optimal estimation for continuous linear systems.

UNIT I

Elements of the theory of stochastic processes, Gauss-Markov sequence model, Gauss- Markov process model.

UNIT II

Optimal estimation for discrete linear systems, optimal prediction of discrete linear systems, optimal filtering for discrete linear systems, optimal filtering in the presence of time-correlated disturbance and measurements.

UNIT III

Classification of smoothed estimates, single and double stage optimal smoothing, optimal fixed-interval smoothing, optimal fixed-point smoothing, optimal fixed-lag smoothing

UNIT IV

Stochastic optimal control for discrete linear systems: Problem formulation, Deterministic problem, stochastic problem

UNIT V

Optimal estimation for continuous linear systems: Problem formulation, equivalent Discrete-time problem, optimal filtering and prediction, optimal fixed-interval smoothing, optimal fixed-point smoothing, optimal fixed-lag smoothing.

Course Outcomes:

After completion of this course students are able to:

- Apply the knowledge of probability theory to stochastic control problems
- Develop optimal filters for process measurements.
- Analyze optimal estimation methods for continuous linear systems.

Reference Books:

1. Stochastic Optimal Linear Estimation and Control, J.S.Meditch, Tata McGraW Hill Book Company, 1969.
2. Optimal Control and Estimation, Robert F. Stengel, Dover Publications, Newyok, 1994.
3. A. Gelb, Applied Optimal Estimation, MIT Press.

I Year - I Semester	L	P	C
	4	0	3

SYSTEM AND PARAMETER IDENTIFICATION

(Common to CS & CE)

Course Educational Objectives:

- To understand the identification of dynamic systems.
- To understand state and parameter estimation of linear systems.
- To identify non-linear state models.

UNIT I Introduction:
System models and model classification, Identification problem, some fields of applications.

UNIT-II Classical models:
Time response and frequency response methods of transfer function evolution, Impulse response identification using cross correlation test and orthogonal series expansion, methods of convolution, model learning technique.

UNIT-III Least square Method:
Least square estimates and its properties, non-recursive least square identification of dynamic system, extensions such as generalised least square repeated least square and instrumental variable method. Recurse Methods: Recursive least square, minimum variance algorithms, stochastic approximation method, maximum likelihood method.

UNIT IV Identification of state variable models:
State Estimatior using Kalman and extended kalman filter, simultaneous state and parameter estimation of linear systems.

UNIT V Non-Linear systems identification:
Identification of a volterra series models, identification of non-linear state models using extended kalman filter, quasilinearization method, invariant imbedding, gradient method, Numerical identification through model following approach.

Course Outcomes:
After completion of this course students are able to:

- Understand the identification problems.
- Develop state estimation using Kalman filters.
- Extend different mathematical models in identifiers non-linear systems.

Reference Books:

1. J.M.Mendel, 'Discrete Techniques Of Parameter Esimation', Marcel Dekker, 1973.
2. F.Eykhoff, 'System Identification, Parameter and State Estimation, John Willey, 1974.
3. A.P.Sage and J.L.Melsa'System Identification',Academic press, 1971.

I Year - I Semester

	L	P	C
	4	0	3

COMPUTER CONTROLLED SYSTEMS
(Common to CS & CE)
(Elective-I)

Course Educational Objectives:

- To introduce basic concepts of multi variable control and real time systems.
- To understand the concept PLCS, SCADA & distributed control systems.
- To understand the concepts of real time systems and their architecture.

UNIT I

Multivariable control:Basic expressions for MIMO systems, Singular values, Stability norms, Calculation of system norms, Robustness, Robust stability. H^2 / H^∞ Theory: Solution for design using H^2 / H^∞ , Case studies, Interaction and decoupling, Relative gain analysis, Effects of interaction, Response to disturbances, Decoupling, Introduction to batch process control.

UNIT II

Digital logic gates, programming in the Boolean algebra system, conversion examples. Ladder diagrams for process control: Ladder diagrams and sequence listings, ladder diagram construction and flow chart for spray process system

UNIT III

PLC Basics: PLC system, I/O modules and interfacing, CPU processor, programming equipment, programming formats, construction of PLC ladder diagrams, devices connected to I/O modules. PLC Programming: Input instructions, outputs, operational procedures, programming examples using contacts and coils. Drill press operation.

UNIT IV

SCADA: Introduction, SCADA Architecture, Different Communication Protocols, Common System Components, Supervision and Control, HMI, RTU and Supervisory Stations, Trends in SCADA, Security Issues

UNIT V

Real time systems- Real time specifications and design techniques- Real time kernels- Inter task communication and synchronization- Real time memory management- Supervisory control-direct digital control- Distributed control- PC based automation.

Course Outcomes:

Aftercompletion ofthis course students are able to:

- Understand Multi variable control systems.
- Design optimal controller using H2 / H∞.
- Develop SCADA Architecture for a specific application.

Reference Books:

1. Shinskey F.G., Process control systems: application , Design and Tuning, McGraw Hill International Edition ,Singapore,1988.
2. Be.langer P.R. , Control Engineering: A Modern Approach, Saunders College Publishing , USA, 1995.
3. Dorf, R.C. and Bishop R. T. , Modern Control Systems , Addison Wesley Longman Inc., 1999
4. Laplante P.A., Real Time Systems: An Engineer.s Handbook, Prentice Hall of India Pvt. Ltd., New Delhi, 2002.
5. Stuart A. Boyer: SCADA-Supervisory Control and Data Acquisition, Instrument Society of America Publications,USA,1999
6. EfimRosenwasser, Bernhard P. Lampe, Multivariable computer-controlled systems: a transfer function approach, Springer, 2006
7. Programmable Logic Controllers – Principle and Applications by John W. Webb and Ronald A. Reiss, Fifth Edition, PHI
8. Programmable Logic Controllers – Programming Method and Applications by JR.Hackworth and F.D Hackworth Jr. – Pearson, 2004.

CONTROL OF SPECIAL MACHINES
(Common to CS & CE)
(Elective-I)

Course Educational Objectives:

- To introduce with Special type of electrical machines.
- To draw the characteristics of special type electrical machines.
- To understand the different control schemes of special machines.

UNIT I

Stepper Motors:Constructional features, Principle of operation, Modes of excitation torque production in Variable Reluctance (VR) stepping motor. Dynamic characteristics, Drive systems and circuit for open loop control, closed loop control of stepping motor.

UNIT II

Switched Reluctance Motors: Constructional features, Principle of operation. Torque equation, Characteristics, Control Techniques, DriveConcept. Permanent Magnet Synchronous Motors: Principle of operation, EMF, power input and torque expressions, Phasor diagram, Power Controllers, Torque speed characteristics, Self-control, Vector control, Current control Schemes.

UNIT III

Permanent Magnet Brushless DC Motors: Commutation in DC motors, Difference between mechanical and electronic commutators, Hall sensors, Optical sensors, Multiphase Brushless motor, Square wave permanent magnet brushless motor drives, Torque and emf equation, Torque-speed characteristics, Controllers-Microprocessors based controller.

UNIT IV

Servomotors: Types, Constructional features, Principle of Operation, Characteristics, Control,–Microprocessor based applications. AC Tachometers: Schematic diagram, Operating principle, numerical problems

UNIT V

Linear Motors: Linear Induction Motor (LIM) Classification, Construction, Principle of operation, Concept of Current sheet, Goodness factor, DC Linear Motor (DCLM) types, Circuit equation, DCLM control, applications.

Course Outcomes:

Aftercompletion ofthis course students are able to:

- Analyze the characteristics of different types of PM type Brushless DC motors and to design suitable controllers
- Apply the knowledge of sensors used in PMSM which can be used for controllers and synchronous machines.
- Evaluate the steady state and transient behavior Linear induction motors
- Analyze the different controllers used in electrical machines to propose the suitability of drives for different industrial applications
- Classify the types of DC Linear motors and apply the knowledge of controllers to propose their applications in real world.
- Able to understand different special electrical machines.
- Able to understand speed control schemes.

Reference Books:

1. Miller, T.J.E. “Brushless Permanent Magnet and Reluctance Motor Drives”, Clarendon Press, Oxford, 1989.
2. Kenjo, T, “Stepping Motors and their Microprocessor control”, Clarendon Press,Oxford, 1989.
3. Naser A and Boldea I, “Linear Electric Motors: Theory, Design and Practical Application”, Prentice Hall Inc., New Jersey,1987.
4. Floyd E Saner,”Servo Motor Applications”, Pittman USA, 1993.
5. Kenjo, T and Naganori, S “Permanent Magnet and brushless DC motors”, Clarendon Press, Oxford, 1989.
6.Generalized Theory of Electrical Machines – P.S.Bimbra-Khanna publications-5th edition-1995.

I Year - I Semester	L	P	C
	4	0	3

MICRO CONTROLLERS& APPLICATIONS

(Common to CS & CE)

(Elective-II)

Course Educational Objectives:

- To understand the architecture of micro controllers.
- To understand memory organization, addressing modes and instruction set of microcontrollers.
- To understand interfacing mechanism of microcontrollers.

UNIT-I: 8051 Microcontrollers, Addressing Modes and Instructions

Introduction to Intel 8 bit and 16 bit Microcontrollers, 8051 Architecture, Registers in 8051, 8051 Pin Description, 8051 Connections, 8051 Parallel I/O Ports, Memory Organization, 8051 Addressing Modes, 8051 Instruction Set and Simple Programs, Using Stack Pointer, 8051 Assembly Language Programming, Development Systems and Tools, Software Simulators of 8051

UNIT-II: 8051 Interrupts, Timer/Counters and Serial Communication

Interrupts in 8051, Timers and Counters, Serial Communication, Atmel Microcontrollers (89CXX and 89C20XX), Architectural Overview of Atmel 89C51 and Atmel 89C2051, Pin Description of 89C51 and 89C2051, Using Flash Memory Devices Atmel 89CXX and 89C20XX

Unit-III: Applications of 8051 and Atmel 89C51 and 89C2051 Microcontrollers

Applications of 8051 and Atmel 89C51 and 89C2051 Microcontrollers- Square Wave Generation- Rectangular Waves- Pulse Generation- Pulse Width Modulation- Staircase Ramp Generation- Sine Wave Generation- Pulse Width Measurement- Frequency Counter

UNIT- IV: PIC Microcontrollers

PIC Microcontrollers: Overview and Features, PIC 16C6X/7X,File Selection Register(FSR), PIC Reset Actions, PIC Oscillator Connections, PIC Memory Organizations, PIC PIC 16C6X/7X Instructions, Addressing Modes, I/O Ports, Interrupts in PIC 16C61/71, PIC 16C61/71 Timers, PIC 16C71 Analog-to-Digital Converter (ADC),

PIC 16F8XX Flash Microcontrollers :Introduction and architecture of 16F8XX, Registers, Program memory, Data Memory, DATA EEPROM and Flash Program EEPROM, Interrupts in 16F877, I/O Ports, Timers

UNIT- V: Interfacing and Microcontroller Applications- Light Emitting Diodes (LEDs), Push Buttons, Relays and Latch Connections, Keyboard Interfacing, Interfacing 7-Segment Displays, LCD Interfacing, ADC AND DAC Interfacing with 89C51 Microcontrollers

Industrial Applications of Microcontrollers - Measurement Applications, Automation and Control Applications

Course Outcomes:

After completion of this course students are able to:

- Understand different micro controller architectures.
- Wave form generation in 8051 and Atmel microcontrollers.
- Develop interfacing techniques for various applications.

Reference Books:

1. Microcontrollers-Theory and Applications by Ajay V Deshmukh, McGraw Hills
2. Microcontrollers by Kennith J ayala, Thomson publishers
3. Microprocessor and Microcontrollers by Prof C.R.Sarma.

PROCESS CONTROL & AUTOMATION

(Common to CS & CE)

(Elective-II)

Course Educational Objectives:

- To understand process control and hierarchies.
- To understand PLCs and distributed control systems.
- To understand industrial and control applications.

UNIT-I

Fundamentals of Process Control: Definition of industrial processes and control, Hierarchies in process control systems block diagram representation of process control system, Control system instrumentation, Codes and Standards, preparation of P&I diagrams.

UNIT-II

Strategies for Computer-Aided Process Control: Open loop control systems, closed loop (feedback) control system, feed forward control system, cascade control system, ratio control, controller design, controller tuning, tuning of P, PI and PID controllers, Ziegler-Nichols tuning method, selection of controllers, predictive control, model based predictive control, multi-variable control system.

UNIT-III

Programmable Logic Controllers (PLCs): Introduction, principles of operation, architecture of programmable logic controllers, programming the programmable controllers, software, configurations, applications.

UNIT-IV

Distributed Control Systems: Introduction, functional requirements of distributed control system, system architecture, distributed control systems configuration and applications ofdistributed control systems.

UNIT-V

Industrial control Applications: Automation of Thermal power plant, automation strategy, distributed system structure, automatic boiler controller, diagnostic function and protection, digital electro-hydraulic governor, automatic start-up system, thermal stress control, man-machine interface, software system, communication system, variable pressure control, combined plant control.

Course Outcomes:

After completion of this course students are able to:

- Develop different control methods for process control.
- Understand system architectures of PLC's and distribute control systems.
- Understand the automation of Thermal power plant

Reference books:

1. Computer based Industrial Control, Krishna Kant, Prentice-Hall India, 2003.
2. Computer Aided Process Control, S.K.Singh, Prentice-Hall India, 2005.
3. Process Dynamics and Control, Seborg, D.E., T.F. Edgar, and D.A. Mellichamp, John Wiley, 2004.
4. Johnson D Curtis, Instrumentation Technology, Prentice-Hall India, (7th Edition), 2002.

I Year - I Semester

	L	P	C
	0	4	2

SIMULATION LABORATORY
(Common to CS & CE)

Course Educational Objectives:

- To develop programming and simulation techniques using MAT LAB/SIMULINK.
- To analyze the stability of LTI systems.
- To develop controllers and compensators for linear systems.

Any 10 of the following experiments are to be conducted.

List of Experiments

The following experiments may be implemented in MATLAB/SIMULINK environment.

1. Preliminary Transformations:
   (a) Transfer function to State space models vice- versa.
   (b) Conversion of Continuous to Discrete time systems vice- versa.
   (c) Verification of controllability and observablity of a given system.
2. Design of state feedback controllers.
3. Stability analysis of a given system using:
   (a) Root Locus.
   (b) Bode plot.
   (c) Lyapunov stability.
4. Implementation of Kalman Filter.
5. Implementation of Least squares error method.
6. Implementation of PID controller and its effects on a given system.
7. Design of Lead, Lag, Lead- Lag compensators using frequency domain analysis.
8. Construction of Simulink model for an Induction motor.

Note: At least four problems may be implemented from the following

9. Solving steady state Ricatti Equation.
10. Construction of Simulink model foe single area and multi area Power system.
11. Solving an optimal control problem using Ricatti equation.

12. Implementation of Full order and minimum order Observer.
13. Implementation of Back-Propagation Algorithm.
14. Implementation of simple Fuzzy controller.
15. Implementationof storage and recall algorithm of Hopfield network model.

Course Outcomes:

After completion of this course students are able to:

- Develop conversion models.
- Do stability analysis of LTI system using various techniques.
- Design and implement various controllers, observers and compensators using MAT LAB/SIMULINK.

I Year - II Semester	L	P	C
	4	0	3

ROBOTICS AND CONTROL
(Common to CS & CE)

Course Educational Objectives:

- To introduce the rotation mechanics among different parts of robot.
- To understand concept of moving dynamics.
- To introduce the trajectory planning and their control.

UNIT I: Introduction-Robot Anatomy

Coordinate frames-mapping- mapping Between rotated frames-mapping between translated frames-mapping between rotated and translated frames-description of objects in space-transformation of vectors—inverting homogeneous transform-fundamental rotation matrices

UNIT-II: Symbolic Modeling of Robots –Direct and Inverse Kinematic Model

Mathematical structure and notations-description of links and joints-kinematic modeling of the manipulator- Denavit-Hatenberg notation-kinematic relationship between adjacent links-manipulator transformation matrix

Manipulator work space – Solvability of kinematic model- -Solution techniques- closed form solution-guidelines to obtain closed form solution.

UNIT III:

Manipulator Differential Motion, Static and Dynamic Modeling

Linear and angular velocity of a rigid body - Relationship between transformation Matrix and angular velocity - Mapping velocity vector-Velocity propagation along links-Manipulator Jacobian - Jacobian Inverse- Jacobian Singularities- Static Analysis

Lagrangian Mechanics – Two degree of freedom Manipulator-Dynamic Model – Lagrange–Euler formulation - Newton –Euler Formulation – comparison of Lagrange–Euler & Newton –Euler Formulations – Inverse Dynamics

UNIT IV: Trajectory Planning and Control of Manipulators

Definitions and planning tasks- terminology-steps in trajectory planning- Joint space techniques-Cartesian space techniques- Joint space Vs Cartesian space Trajectory planning.

Open and close loop control – The manipulator control problem – Linear control schemes- Characteristics of second order linear systems- Linear Second order-SISO model of a manipulator joint- Joint Actuators- partitioned PD control scheme –PID control scheme – computed torque control- force control of robotic manipulators – description of force control tasks –Force-control strategies-Hybrid position/ force control- Impedance Force/Torque control

UNIT V: Robotic Sensors and Applications

Sensing- Sensors in robotics – Kinds of sensors used in robotics- -Robotic vision- Robotic vision- Industrial applications of vision controlled robotic systems- process of Imaging- Architecture of robotic vision systems- Image Acquisition- Image representation-Image processing – Industrial applications –material handling – Process applications – Assembly applications – Inspection application – Principles of Robot applications and application planning, Justification of robots- Robot safety

Course Outcomes:

Aftercompletion of this course the students are able to:

- Do modeling of Robots with various mapping techniques.
- Do planning and better control of manipulators with open and closed loop controls.
- Apply for various robot applications and their safety measures as criteria.

Reference Books:

1. Robotics and control –RKMittal And I J Nagrath TMH Publishers-1st edition-2003
2. MikellP,WeissG.M.,Nagel R.N., Odrey N.G., Industrial Robotics, McGraw Hill,1986.
3. Deb.S.R- Robotics Technology and flexible automation, Tata McGraw Hill, 1994.
4. Asfahi C.R. - Robotics and manufacturing automation, John wiley ,1992.
5. Klafter R.D.-Chimielewski T.A &Neign M., Robotics engineering: An integrated approach, Prentice Hall of India Pvt.Ltd., 1994.

I Year - II Semester

L	P	C
4	0	3

NONLINEAR SYSTEMS ANALYSIS
(Common to CS & CE)

Course Educational Objectives:

- To introduce nonlinear systems.
- To understand the stability concepts.
- To understand the concept of variable structure controllers.

UNIT-I

Linear versus nonlinear systems - Fundamentals, common nonlinearities (saturation, dead - zone, on - off non - linearity, backlash, hysteresis) and their describing functions.Existence of limit cycles. Linearization: Exact linearization, input - state linearization, input - output linearization.

UNIT-II

Phase plane analysis: Phase portraits, Singular points characterization. Analysis of non - linear systems using phase plane technique, determination of limit cycles, Poincare index, Bendixon theory.

UNIT-III

Frequency domain analysis of feedback systems: Absolute stability - Circle criterion - Popov criterion. Describing function analysis of nonlinear systems.

UNIT-IV

Concept of stability, stability in the sense of Lyapunov and absolute stability. Zero - input and BIBO stability. Second (or direct) method of Lyapunov stability theory for continuous and discrete time systems.

UNIT-V

Concept of variable - structure controller and sliding control, reaching condition and reaching mode, implementation of switching control laws.Reduction of chattering in sliding and steady state mode. Some design examples of nonlinear systems such as the ball and beam, flight control, magnetic levitation and robotic manipulator etc.

Course Outcomes:

Aftercompletion ofthis course students are able to:

- Analyze nonlinear systems.
- Do stability analysis using different methods.
- Design controllers for nonlinear systems**.**

Reference Books:

1. J. E. Slotine and Weiping LI, Applied Nonlinear Control, Prentice Hall,
2. Hassan K. Khalil, Nonlinear Systems, Prentice Hall, 1996.
3. SankarSastry, Nonlinear Systems Analysis, Stability and Control.
4. M. Vidyasagar, Nonlinear Systems Analysis, Prentice - Hall International editions,1993

I Year - II Semester

L	P	C
4	0	3

DIGITAL SIGNAL PROCESSING
(Common to CS & CE)

Course Educational Objectives:

- To understand the representation of discrete time systems and system functions.
- To understand discrete transformation techniques and their computation procedure.
- To understand the various digital filters design principles.

UNIT-I

Applications of Z Transforms: Review of Discrete Time Sequences and systems – Review of Z-transforms - System functions H(z) of Digital Systems - Stability Analysis - Structure and Realization of Digital Filters: direct – canonic – cascade and parallel form of realization.

UNIT-II

Discrete Fourier Transform (DFT): Discrete time Fourier transform – Discrete Fourier series(DFS) representation of periodic sequences – properties of DFS – Discrete Fourier transform (DFT) – computation of DFT – properties of DFT – convolution of sequences using DFT – IDFT.

UNIT-III

Discrete and Fast Fourier Transform (DFT & FFT): Radix – 2 Decimation in Time (DIT) and Decimation in Frequency (DIF) FFT Algorithms, IDFT using FFT - Applications of FFT in spectrum analysis and filtering.

UNIT-IV

IIR Digital Filter Design Techniques: Design of IIR Filters from Analog Filters - Analog Filters Approximations: Butterworth and Chebyshev - Frequency Transformations - General Considerations in Digital Filter Design - Bilinear Transformation Method - Step and Impulse Invariance Technique.

UNIT-V

Design of FIR Filters: FIR filters design using Fourier Series Method - Window Function Techniques - Comparison of IIR a FIR Filters. Applications of DSP in Speech Processing.

Course Outcomes:

After completion of this course students are able to:

- Analyze the representation of discrete time system and obtain system functions for design of filters.
- Analyze the computation algorithms of DFT & FFT.
- Design the IIR & FIR filters using various techniques.

Reference Books:

1. "Digital Signal Processing", Alan Oppenheim & Ronald W.Schafer; PHI,2000
2. "Digital signal processing A computer based approach", SanjitK.Mitra , Tata McGraw Hill,2nd Edition,2000.
3. "Digital signal processing principles,Algorithms and Applications" Jhon G.Proakis,DimitrisG.Manolakis, Third Edition,2000,PHI.
4. "Digital Signal Processing', P.RameshBabu, SCITECH Publishers,2004.

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I Year - II Semester	L	P	C
	4	0	3

OPTIMAL CONTROL THEORY
(Common to CS & CE

Course Educational Objectives:

- To introduce overall performance measures with variable functions.
- To understand dynamic programming methods.
- To introduce various regulators and algorithms.

UNIT-I

Introduction: Overview of optimization problem, Performance indices, Formulation of Optimal control problem, constrained optimization, unconstrained optimization, Local optimality, Global optimality and their solutions using different techniques, convex sets, convex function, convex programming problem , Sufficient conditions for convex programming problem.

UNIT-II

Calculus of Variation: fundamental concepts, Functions and Functional, Fundamental Theorem of the calculus of Variations, Functional of a single function , Functional involving several independent functions, necessary conditions for optimal control.

UNIT-III

Linear quadratic regulator: Weighting matrices, Finite time Linear Quadratic Regulator, Solution to matrix differential Ricatti equation, Infinite time Linear Quadratic Regulator, Frequency domain Interpretation.

UNIT-IV

Dynamic programming: Principles of optimality, backward solution, forward solution, characteristics of Dynamic Programming solution, Pontryagin Minimum Principle, Hamilton-Jacobi Bellman equation.

UNIT-V

Numerical determination of optimal trajectories: Two point boundary value problem, The method of Steepest descent algorithm, variation of extremals, variation of extremal algorithm, Gradient projection algorithm.

Course Outcomes:

After completion of this course students are able to:

- Develop linear quadratic regulators.
- Determine optimal trajectories.
- Understand various linear and infinite time regulators with better interpretation.

Reference Books:

1. Optimal Control Theory an Introduction, Donald E.Kirk, Prentice –Hall Network Series
2. Optimal Control systems, D.S.Naidu CRC Press
3. Optimal Control Theory, B.D.O.Anderson& Moore-PHI-1991
4. Optimum System Control –A.P.Sage
5. Introduction to optimum design, JasbirS.Arora, Elesevier, 2005.
6. D.P.Bertsekas, Dynamic Programming and optimal Control, Vol.I, 2nd edition, Athena Scientific, 2000.

I Year - II Semester	L	P	C
	4	0	3

AI TECHNIQUES
(Common to CS & CE)
(Elective-III)

Course Educational Objectives:

- To have knowledge on concept of neural network.
- To know different types of neural networks and training algorithms.
- To understand the concept of genetic algorithm.
- To have the knowledge on fuzzy logic and design of fuzzy logic controllers.
- To know the applications of AI Techniques in control engineering applications.

UNIT – I

Introduction to Neural Networks: Introduction, Humans and Computers, Biological neural networks, Historical development of neural network, Terminology and Topology, Biological and Artificial Neuron Models. Basic learning laws..

UNIT- II

Feed Forward Neural Networks: Introduction, Perceptron models: Discrete, Continuous and multi-Category, Training Algorithms: Discrete and Continuous Perceptron Networks, Perceptron Convergence theorem, Limitations of the Perceptron model, Generalised delta learning rule, Feedforward recall and error back propagation training, radial basis function algorithms, Hope field networks.

UNIT III

Genetic Algorithms &Modelling: Introduction-encoding-fitness function-reproduction operators-genetic operators-cross over and mutation-generational cycle-convergence of genetic algorithm.

UNIT – IV

Classical and Fuzzy Sets: Introduction to classical sets - properties, Operations and relations; Fuzzy sets, Membership, Uncertainty, Operations, properties, fuzzy relations, cardinalities, membership functions.Fuzzy Logic System Components:Fuzzification, Membership value assignment, development of rule base and decision making system, Defuzzification to crisp sets, Defuzzification methods.

UNIT V

Application of AI Techniques: Fuzzy control systems: simple fuzzy logic controllers & GA with examples, image processing, room heating system, Neural Networks: character recognition networks, inverted pendulum neuro controller, Neural network for Robot kinematics

Course Outcomes:

After completion of this course students are able to:

- Understand neural networks and analyze different types of neural networks.
- Design training algorithms for neural networks.
- Develop algorithms using genetic algorithm for optimization.
- Analyze and design fuzzy logic systems.
- Apply AI Techniques in control engineering applications.

Reference Books:

1. Neural Networks, Fuzzy logic, Genetic algorithms: synthesis and applications by Rajasekharan and Pai – PHI Publication.
2. Introduction to Artificial Neural Systems - Jacek M. Zuarda, Jaico Publishing House, 1997.

EMBEDDED REAL TIME OPERATING SYSTEMS
(Common to CS & CE)
(ELECTIVE-III)

Course Educational Objectives:

- To impart the general embedded system concepts with design of embedded modeling and usage.
- To explain the concepts of real time operating systems based embedded system design.
- To do different case studies along with designing examples with RTOS**.**

UNIT I: Introduction
History of Embedded Systems, Major Application Areas of Embedded Systems, Purpose of Embedded Systems, Core of the Embedded System, Sensors and Actuators, Communication Interface, Embedded Firmware.

UNIT II: Hardware Software Co-Design and ProgrammeModelling
Characteristics of an Embedded System, Quality Attributes of Embedded Systems, Fundamental Issues in Hardware Software Co-Design, Computational Models in Embedded Design, Introduction to Unified Modeling Language (UML),Hardware Software Trade-offs.

UNIT III: Real Time Operating Systems
OS Services, Process Management, Timer .Functions, Event Functions, Memory Management, Device, File and IO Subsystems Management, Interrupt Routines in RTOS Environment and Handling of Interrupt Source Calls, Real-time Operating Systems, Basic-Design an RTOS, RTOS Task Scheduling Models, Interrupt Latency and Response of the Tasks as Performance Matrices, OS Security Issues.

UNIT IV:Real-Time Operating Systems (RTOS) Based Embedded System Design
Operating System Basics, Types of Operating Systems, Tasks, Process and Threads, Multiprocessing and Multitasking, Task Scheduling, Threads, Processes and Scheduling :Putting them Altogether, Task Communication, Task Synchronization, Device Drivers, How to Choose an RTOS.

UNIT V: Design Examples and Case Studies of Progam Modeling and RogrammingWithRTOS-II
Case study of Communication between Orchestra Robots, Embedded Systems in Automobile, Case study of an Embedded System for an Adaptive Cruise Control(ACC) System in a Car, Case study of an Embedded System for a Smart Card, Case study of a Mobile Phone Software for Key Inputs.

Course Outcomes:

After completion of this course students are able to:

- Analyze and understand the concepts of embedded systems along with design aspects.
- Understand the concept of UML and programme modeling with better hardware-software trade-offs.
- Get the concept of synchronization between RTOs based embedded system design with different applications.
- Able to analyze different types of examples as case studies of present day applications of Smart card, ACC system in a car etc.

Reference Books:

1. Introduction to Embedded System- Shibu KV, Mc-Graw Hill Higher Edition.
2. Embedded Systems Architecture, Programming and Design- Raj Kamal, Second Edition, McGraw-Hill Companies.
3. Embedded System Design by Peter Marwedel, Springer.
4. Embedded System Design – A Unified Hardware/Software Introduction-Frank Vahid, Tony D. Givargis, John Wiley, 2002.
5. Embedded/ Real Time Systems-KVKK Prasad, Dreamtech Press, 2005.
6. An Embedded Software Primer- David E. Simon, Pearson Ed. 2005.

I Year - I Semester	L	P	C
	4	0	3

DECISION AND ESTIMATION THEORY
(Common to CS & CE)
(Elective-IV)

Course Educational Objectives:

- To make decisions with respect to single and multiple observations based on digital format.
- To analyze different types of multiple decision tests in general and Gaussian case.
- To discuss different types of estimation methods tofind the objective through normal and Gaussian noise.
- To analyze estimators along with their significance properties in terms of sensitivity and error based.

UNIT-I:
Binary Decisions for single and multiple observations: Maximum-Likelihood decision, Neyman-Pearson, Probability-of-error, Bayes risk and Min-Max Criteria. Vector observations, general Gaussian problem.

UNIT-II:
Multiple decisions: Bayes risk, Probability of error general case and probability of error Gaussian case. Sequential Bayes tests.

UNIT-III:
Fundamentals of estimation: Maximum-Likelihood, Bayes cost methods. Relationship of estimators. Linear Minimum-Variance and Least-Squares estimation.

UNIT-IV:
Estimation with Gaussian noise: Linear observations, Sequential Estimation, Nonlinear Estimation and State Estimation.

UNIT-V:
Properties of Estimators: Unbiased Estimators, Efficient Estimators, Asymptotic Properties, Sensitivity and error analysis.

Course Outcomes:

Aftercompletion ofthis course students are able to:

- Digital based decisions and study their effectiveness is studied.
- Better decisions in form of single and multiple cases with better test analysis.
- Different fundamental and Gaussian state estimation methods.
- Various estimators to do the sensitivity and error analysis of different problems.

Reference Books:

1. Decision and estimation theory, J. M. Melsa and D.L. Cohen, Springer-Verlag, 1978
2. H.L. Van Trees, Detection, Estimation, and Modulation Theory, vol. I. Wiley, New York, 1968.
3. S. Kay, Fundamentals of Statistical Signal Processing: Detection Theory, Prentice Hall, 1998.
4. S. Kay, Fundamentals of Statistical Signal Processing: Estimation Theory, Prentice Hall, 1993.
5. H. V. Poor, An Introduction to Signal Detection and Estimation, 2nd Ed., Springer-Verlag, 1994.
6. L. L. Scharf, Statistical Signal Processing: Detection, Estimation and Time Series Analysis,Addison-Wesley, 1991.
7. R. Hippenstiel, Detection Theory: Applications and Digital Signal Processing, CRC Press, 2002.

EMBEDDED COMPUTER CONTROL
(Common to CS & CE)
(Elective-IV)

Course Educational Objectives:

- To impart the basic knowledge of embedded computer control concepts.
- To get familiarize with the basic architecture, selection, memory segments.
- To understand the concept of interfacing techniques using different controllers for fine tuning of applications.

UNIT-I
Overview of design challenges and design metrics, Formalisms for system design based various technologies, Combinational logic design, Sequential logic design.

UNIT-II
Basic Architecture, Programming view, Development Environment, Microprocessor selection, General-purpose processor design.

UNIT-III
Timers, UART, Pulse width modulation, LCDs, Keyboards, ADCs and DACs, Memory system mechanisms, Memeory hierarchy and cache Memory management units.

UNIT-IV
Bus architecture, Interrupts, Direct memory access, Introduction to advanced interfacing techniques, Requirement specifications, Design alternatives

UNIT-V
Open-loop and closed-loop control systems, PID controller, Software implementation of PID controller, PID tuning and practical issues

Course Outcomes:
After completion of this course students are able to:

- Understand the basic design concepts of digital integration techniques.
- Understand the overall architecture along with memory management units.
- Develop the operation techniques with interfacing to practical applications along with fine tuning for better output.

Reference Books:

1. Frank Vahid and Tony Givargis, Embedded System Design: A Unified Hardware/Software Introduction, John Wiley, 2002.
2. Frederick M. Cady , Microcontrollers and Microcomputers Principles of Software, and Hardware Engineering , Second Edition, Oxford University Press ,2009
3. Peter Marwedel, Embedded System Design, Springer, 2006
4. Wayne Wolf, Computers as Components, 2nd Edition, Morgan Kaufmann, 2008

I Year - II Semester	L	P	C
	0	4	2

ADVANCED CONTROL SYSTEM LABORATORY

(Common to CS & CE)

Course Educational Objectives:

- To design and observe the performance of control components.
- To design and observes the performance of controllers.

Any 10 of the following experiments are to be conducted.

List of Experiments

1. To obtain the moment of inertia and then develop the transfer function of the given DC Motor for (a) Armature controlled case and (b) Field controlled case. Draw the relevant block diagrams.
2. To conduct experiments on the given amplidyne for (a) To obtain the transfer function (b) To obtain the load characteristics under different levels of compensation (c) To obtain the characteristics of a metadyne.
3. To design a Lag-Lead compensator and to obtain the characteristics by simulation UsingMATLAB®. Verify the performance using experiments with the compensator circuit made of passive elements.
4. To set up a system for closed loop voltage regulation for a dc separately excited generator using amplidyne and to obtain its characteristics
5. To obtain the model of the Inverted pendulum and study the closed loop performance usingexperiments on Bytronic® Inverted Pendulum
6. To conduct experiments on the Level Process Control Station and to study the working of a level control loop.
7. To set up a closed loop feedback control system using the FEEDBACK® MS150 DC Modular Servo System-with velocity (rate) feedback.
8. Temperature controller using PID.
9. To set up an open loop control system using Micro-processor for controlling the stepper motor
10. To design a Lead compensator and to obtain the characteristics by simulation using MATLAB®. Verify the performance using experiments with the compensator circuit made of passive elements.
11. Effect of P, PD, PI, PID Controller on a second order systems
12. Programmable logic controller – Study and verification of truth tables of logic gates, simple Boolean expressions and application of speed control of motor.

Course Outcomes:

After completion of this course students are able to:

- Design circuits to observe the performance of components.
- Design controllers.
- Design speed control methods for motors using PLCs.

Reference Books:

1. Gene F Franklin, J David Powell, Abbas EmamiNaeini, Feedback Control of Dynamic Systems, 4th Ed, Pearson Education Asia, 2002
2. Graham C Goodwin, Stefan F Graebe, Mario E Salgado, Control System Design, Prentice Hall India, 2003.
3. John J D'Azzo, Constantine H Houpis, Stuart N. Sheldon, Linear Control System Analysis & Design with MATLAB, 5th Ed, Marcel Dekker, 2003
4. John E Gibson, Franz B. Tuteur, Control System Components, McGrawHill, 1958
5. Users' Manual for FEEDBACK® MS150 AC Modular Servo System
6. Users' Manual for 8085n Microprocessor kit, ©ViMicroSystems.
7. www.mathworks.com
8. Users' Manual for Bytronic® Inverted Pendulum.
9. Users' Manual for Level Process Station, ©Vi McroSystems

II Year - III Semester

L	P	C
0	0	2

COMPREHENSIVE VIVA-VOCE

II Year - III Semester

L	P	C
0	0	2

SEMINAL - I

II Year - III Semester	L	P	C
	0	0	16

PROJECT WORK PART - I

II Year - IV Semester	**L**	**P**	**C**
	0	**0**	**2**

SEMINAR - II

II Year - IV Semester	**L**	**P**	**C**
	0	**0**	**18**

PROJECT WORK PART - II

ACADEMIC REGULATIONS &
COURSE STRUCTURE

For

HIGH VOLTAGE ENGINEERING (HVE) &
POWER SYSTEMS WITH EMPHASIS ON H. V. ENGINEERING (PSHVE)

(Applicable for batches admitted from 2016-2017)

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY: KAKINADA
KAKINADA - 533 003, Andhra Pradesh, India

I Semester

S. No.	Subject	L	P	Credits
1	Generation and Measurement of High Voltages	4	--	3
2	Dielectric and Insulation Engineering	4	--	3
3	HVDC Transmission	4	--	3
4	Power System Operation and Control	4	--	3
5	**Elective – I** i. Artificial Intelligence Techniques ii. Advanced Digital Signal Processing iii. Smart Grid Technologies iv. Breakdown Phenomenon in Electrical Insulation	4	--	3
6	**Elective – II** i. GAS Insulated Systems and Substations ii Collision Phenomena in Plasma Science iii. Advanced EM Fields	4	--	3
7	High Voltage Laboratory	--	4	2
Total Credits				**20**

II Semester

S. No.	Subject	L	P	Credits
1	High Voltage Testing Techniques	4	--	3
2	EHVAC Transmission	4	--	3
3	Surge Phenomenon & Insulation Coordination	4	--	3
4	Advanced Power System Protection	4	--	3
5	Elective – III i. Partial Discharge in HV Equipment ii. High Voltage systems using EMTP Analysis iii. Pulse Power Engineering	4	--	3
6	Elective – IV i. Flexible AC Transmission Systems ii. Power System Deregulation iii. Reactive Power compensation & Management	4	--	3
7	Simulation Laboratory	--	4	2
Total Credits				**20**

III Semester

S. No.	Subject	L	P	Credits
1	Comprehensive Viva-Voce	**--**	**--**	2
2	Seminar – I	--	--	2
3	Project Work Part - I	--	--	16
Total Credits				**20**

IV Semester

S. No.	Subject	L	P	Credits
1	Seminar – II	--	--	2
2	Project Work Part - II	--	--	18
Total Credits				**20**

I Year - I Semester	L	P	C
	4	0	3

GENERATION & MEASUREMENT OF HIGHVOLTAGES
(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE)

Prerequisites: Basicsof Electrical circuits, Electronics and measurements for testing purpose
Course Educational Objectives:

- To study the numerical methods for analyzing electrostatic field problems.
- To study the fundamental principles of generation of high voltage for testing.
- To study the methods for measurement of high AC, DC and transient voltages.
- To Study the measurement techniques for high AC, DC and impulse currents.

UNIT 1- Electrostatic fields and field stress control: Electric fields in homogeneous Isotropic materials and in multi dielectric media-Simple configurations-field stress control. Methods of computing electrostatic fields-conductive analogues-Impedance networks Numerical techniques-finite difference method-finite element method and charge simulation method.

UNIT 2-Generation of High AC & DC Voltages:
Direct Voltages: AC to DC conversion methods electrostatic generators-Cascaded Voltage Multipliers.
Alternating Voltages: Testing transformers-Resonant circuits and their applications, Tesla coil.

UNIT 3-Generation of Impulse Voltages :
Impulse voltage specifications-Impulse generations circuits-Operation, construction and design of Impulse generators-Generation of switching and long duration impulses.
Impulse Currents : Generation of High impulse currents and high current pulses.

UNIT 4- Measurement of High AC & DC Voltages :
Measurement of High D.C. Voltages : Series resistance meters, voltage dividers and generating voltmeters.
Measurement of High A.C. Voltages : Series impedance meters electrostatic voltmeters potential transformers and CVTS-voltage dividers and their applications.

UNIT 5-Measurement of Peak Voltages : Sphere gaps, uniform field gaps, rod gaps.Chubb-Fortesque methods.Passive and active rectifier circuits for voltage dividers.
Measurement of Impulse Voltages : Voltage dividers and impulse measuring systems-generalized voltage measuring circuits-transfer characteristics of measuring circuits-L.V. Arms for voltage dividers-compensated dividers.
Measurement of Impulse Currents : Resistive shunts-current transformers-Hall Generators and Faraday generators and their applications-Impulse Oscilloscopes.

Course Outcomes:

After completion of the course the student will be able to:

- Understand numerical computation of electrostatic problems.
- Understand the techniques of generation of high AC, DC and transient voltages.
- Measure high AC, DC and transient voltages.
- Measure high AC, DC and transient currents.

Reference Books :

1. High Voltage Engineering – by E.Kuffel and W.S.Zaengl. Pergaman press Oxford, 1984.
2. High Voltage Engineering – by M.S.Naidu and V.Kamaraju, Mc.Graw-Hill Books Co., New Delhi, 2nd edition, 1995.
3. High Voltage Technology – LL Alston, Oxford University Press 1968.
4. High Voltage Measuring Techniques – A. Schwab MIT Press, Cambridge,USA, 1972.
5. Relevant I.S. and IEC Specifications.

I Year - I Semester

L	P	C
4	0	3

DIELECTRICS AND INSULATION ENGINEERING

(Common to HVE, PSHVE)

Prerequisites: Concepts of High voltage engineeringand basic physics.

Course Educational Objectives:

- To understand the electrical properties of insulating materials.
- To understand the principles of dielectric failure in insulating materials.
- To understand the application of insulating materials in different electrical apparatus.

UNIT 1-Dielectrics and Insulating Materials: Review of Dielectric Phenomenon: Complex permittivity – Polarization - Relaxation and resonant models. Solid, Liquid and Gaseous insulating materials-Physical, Thermal & Electrical properties-Classification of Insulating Materials.

UNIT 2-Solid Insulating Materials: Organic Fiber materials Ceramics & Synthetic polymers and their applications.
Liquid Insulating Materials: Insulating oils, their properties and applications.
Gaseous Insulating Materials: Air and SF_6- applications in electrical apparatus.

UNIT 3-Breakdown phenomenon in gaseous and vacuum insulation: Insulation and decay processes-transition from self-sustained discharges to breakdown-Townsend and streamer discharge Paschen's law,Penning effect-Time lags-Surge breakdown voltage-Breakdown an non uniform fields-Vacuum insulation and vacuum breakdown.

UNIT 4-Breakdown Phenomenon in Liquid and Solid Insulation: pure and commercial liquids-suspended particle and bubble theories-stressed oil volume theory-Breakdown in solid insulation Intrinsic breakdown-Treeing and tracking phenomenon-Thermal breakdown—Breakdown in composite dielectrics.

UNIT 5-Insulation Engineering: Insulation design for power cables, capacitors, bushings, switchgear, transformers and rotating machines-resents trends.

Course Outcomes:

After completion of the course, students will be able to:

- Properties of insulating materials.
- Electrical breakdown in gas and vaccum insulation.
- Electrical breakdown in liquid and solid insulation.
- Insulation design in electrical power apparatus.

Reference Books:

1. High Voltage Engineering – by E.Kuffel and W.S. ZaegnlPergamon press, Oxford, 1984.
2. High Voltage Engineering – by M.S.Naidu and V.Kamaraju, Tata McGraw-Hill Books Co., New Delhi, 2nd edition, 1995.
3. Electrical Engineering Materials – B. Tareev, M.I.R. Publications, MOSCOW.
4. Physics of Dielectrics - B. Tareev, M.I.R. Publications, MOSCOW
5. High Voltage Technology - LL Alston, Oxford University Press 1968.
6. Insulation Engineering- by Arora ,John Wiley & Sons
7. Insulating Materials-by Dekker,S.Chanda& Co
8. Dieletrics and waves-by vonhipple,John Wiley & Sons

I Year - I Semester	L	P	C
	4	0	3

HVDC TRANSMISSION

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE,PSHVE, PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

Prerequisites: Knowledge onPower Electronics, Power Systems and High Voltage Engineering

Course Educational Objectives:

- To learn various schemes of HVDC transmission.
- To learn about the basic HVDC transmission equipment.
- To learn the control of HVDC systems.
- To be exposed to the interaction between HVAC and HVDC system.
- To be exposed to the various protection schemes of HVDC engineering.

UNIT -1: Limitation of EHV AC Transmission and advantages of HVDC Technical economical reliability aspects.HVDC Transmission: General considerations, Power Handling Capabilities of HVDC Lines, Basic Conversion principles, static converter configuration. Types of HVDC links-Apparatus and its purpose.

UNIT-2: Static Power Converters: 6-pulse bridge circuit and 12-pulse converters, converter station and Terminal equipment, commutation process, Rectifier and inverter operation, equivalent circuit for converter – special features of converter transformers. Comparison of the perform of diametrical connection with 6-pulse bridge circuit

UNIT-3 : Control of HVDC Converters and systems : constant current, constant extinction angle and constant Ignition angle control. Individual phase control and equidistant firing angle control, DC power flow control. Factors responsible for generation of Harmonics voltage and current harmonics effect of variation of α and μ. Filters Harmonic elimination.

UNIT-4 : Interaction between HV AC and DC systems – Voltage interaction, Harmonic instability problems and DC power modulation. Development of DC circuit Breakers, Multi-terminal DC links and systems; series, parallel and series parallel systems, their operation and control.

UNIT -5 : Transient over voltages in HV DC systems : Over voltages due to disturbances on DC side, over voltages due to DC and AC side line faults. Converter faults and protection in HVDC Systems: Converter faults, over current protection - valve group, and DC line protection, circuit breakers. Over voltage protection of converters, surge arresters.

Course Outcomes:

After completion of the course, students will be able to:

- Understand the various schemes of HVDC transmission.
- Understand the basic HVDC transmission equipment.
- Understand the control of HVDC systems.
- Understand the interaction between HVAC and HVDC system.
- Understand the various protection schemes of HVDC engineering.

Reference Books:

1. S Kamakshaih and V Kamaraju:HVDC Transmission- MG hill.
2. K.R.Padiyar : High Voltage Direct current Transmission, Wiley Eastern Ltd., New Delhi – 1992.
3. E.W. Kimbark : Direct current Transmission, Wiley Inter Science – New York.
3. J.Arillaga : H.V.D.C.Transmission Peter Peregrinus ltd., London UK 1983
4. Vijay K Sood:HVDC and FACTS controllers:Applications of static converters in power systems by, Kluwer Academic Press.

I Year - I Semester	L	P	C
	4	0	3

POWER SYSTEM OPERATION AND CONTROL
(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE)

Prerequisites: Knowledge on Power Generation Engineering, Power Transmission Engineering.

Course Educational Objectives:

- To Study the unit commitment problem for economic load dispatch.
- To study the load frequency control of single area and two area systems with and without control.
- To study the effect of generation with limited energy supply.
- To study the effectiveness of interchange evaluation in interconnected power systems.

UNIT-1 : Unit commitment problem and optimal power flow solution : Unit commitment : Constraints in UCP,UC solutions. Methods-priority list method, introduction to Dynamic programming Approach.

UNIT-2 : Single area load Frequency Control: Necessity of keeping frequency constant. Definition of control area, single area control, Block diagram representation of an isolated Power System, Steady State analysis, Dynamic response-Uncontrolled case. Proportional plus Integral control of single area and its block diagram representation, steady state response, load frequency control and Economic dispatch control.

UNIT-3 : Two area Load Frequency Control: Load frequency control of 2-area system : uncontrolled case and controlled case, tie-line bias control. Optimal two-area LF control-steady state representation, performance Index and optimal parameter adjustment.

UNIT-4 : Generation with limited Energy supply : Take-or-pay fuel supply contract, composite generation production cost function. Solution by gradient search techniques, Hard limits and slack variables, Fuel scheduling by linear programming.

UNIT-5 : Interchange Evaluation and Power Pools Economy Interchange, Economy interchange Evaluation, Interchange Evaluation with unit commitment, Multiple Interchange contracts. After-the-fact production costing, Transmission Losses in transaction Evaluation, other types of Interchange, power pools.

Course Outcomes:
After completion of the course, students will be able to:

- Determine the unit commitment problem for economic load dispatch.
- Get the knowledge of load frequency control of single area and two area systems with and without control.
- Know the effect of generation with limited energy supply.
- Determine the interchange evaluation in interconnected power systems.

Reference Books :

1. Modern Power System Analysis - by I.J.Nagrath&D.P.Kothari, Tata McGraw-Hill Publishing Company ltd, 2nd edition.
2. Power system operation and control PSR Murthy B.S publication.
3. Power Generation, Operation and Control - by A.J.Wood and B.F.Wollenberg,Johnwiley& sons Inc. 1984.
4. Electrical Energy Systems Theory - by O.I.Elgerd, Tata McGraw-Hill Publishing Company Ltd, 2nd edition.
5. Reactive Power Control in Electric Systems - by TJE Miller, John Wiley & sons.

I Year - I Semester

L	P	C
4	0	3

ARTIFICIAL INTELLIGENCE TECHNIQUES

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE)

(Elective-I)

Prerequisites: Basic knowledge on human biological systems, concept of optimization and electrical engineering.

Course Educational Objectives:

- To have knowledge on concept of neural network.
- To know different types of neural networks and training algorithms.
- To understand the concept of genetic algorithm and its application in optimization.
- To have the knowledge on fuzzy logic and design of fuzzy logic controllers.
- To know the applications of AI Techniques in electrical engineering.

UNIT – 1: Introduction to Neural Networks

Introduction, Humans and Computers, Biological Neural Networks, Historical development of neural network, Terminology and Topology, Biological and artificial neuron models, Basic learning laws.

UNIT- 2:Feed Forward Neural Networks

Introduction, Perceptron models: Discrete, continuous and multi-category, Training algorithms: Discrete and Continuous Perceptron Networks, Perceptron convergence theorem, Limitations and applications of the Perceptron model, Generalized delta learning rule, Feedforward recall and error back propagation training-Radial basis function algorithms-Hope field networks

UNIT -3: Genetic algorithms &Modelling-introduction-encoding-fitness function-reproduction operators-genetic operators-cross over and mutation-generational cycle-convergence of genetic algorithm

UNIT – 4:Classical and Fuzzy Sets

Introduction to classical sets - properties, operations and relations; Fuzzy sets, membership, Uncertainty, operations, properties, fuzzy relations, cardinalities, membership functions.

Fuzzy Logic System Components-Fuzzification, Membership value assignment, development of rule base and decision making system, defuzzification to crisp sets, defuzzification methods.

UNIT 5: Application of AI Techniques-load forecasting-load flow studies-economic load dispatch-load frequency control-reactive power control-speed control of dc and ac motors

Course Outcomes:

After completion of the course, students will be able to :

- Understand neural networks and analyze different types of neural networks.
- Design training algorithms for neural networks.
- Develop algorithms using genetic algorithm for optimization.
- Analyze and designfuzzy logic systems.
- Apply AI Techniques in electrical engineering.

Reference Books:

1. Neural Networks, Fuzzy logic, Genetic algorithms: synthesis and applications by Rajasekharan andPai – PHI Publication.
2. Introduction to Artificial Neural Systems - Jacek M. Zuarda, Jaico Publishing House, 1997.

ADVANCED DIGITAL SIGNAL PROCESSING

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE)

(Elective I)

Perquisites: Knowledge on signal processing and Z-transform.

Course Educational Objectives:

- To have knowledge on structures of different digital filters.
- To design digital filters with different techniques.
- To understand the implementation aspects of digital filters.
- To analyze the effect of finite word length in signal processing.
- To understand power spectrum estimation techniques in signal processing.

UNIT-1: Digital Filter Structure

Block diagram representation-Equivalent Structures-FIR and IIR digital filter Structures All pass Filters-tunable IIR Digital Filters-IIR tapped cascaded Lattice Structures-FIR cascaded Lattice structures-Parallel-Digital Sine-cosine generator-Computational complexity of digital filter structures.

UNIT-2: Digital filter design

Preliminary considerations-Bilinear transformation method of IIR filter design-design of Low pass high pass-Band pass, and Band stop- IIR digital filters-Spectral transformations of IIR filters, FIR filter design-based on Windowed Fourier series- design of FIR digital filters with least –mean- Square-error-constrained Least-square design of FIR digital filters

UNIT-3: DSP algorithm implementation

Computation of the discrete Fourier transform- Number representation-Arithmetic operations-handling of overflow-Tunable digital filters-function approximation.

UNIT-4: Analysis of finite Word length effects

The Quantization process and errors- Quantization of fixed -point and floating -point Numbers-Analysis of coefficient Quantization effects - Analysis of Arithmetic Round-off errors, Dynamic range scaling-signal- to- noise ratio in Low -order IIR filters-Low-Sensitivity Digital filters-Reduction of Product round-off errors using error feedback-Limit cycles in IIR digital filters-Round-off errors in FFT Algorithms.

UNIT 5: Power Spectrum Estimation

Estimation of spectra from Finite Duration Observations signals – Non-parametric methods for power spectrum Estimation – parametric method for power spectrum Estimation, Estimation of spectral form-Finite duration observation of signals-Non-parametric methods for power spectrum estimation-Walsh methods-Blackman & torchy method.

Course Outcomes:

After completion of the course, students will able to:

- Describe structure of digital filters.
- Design digital filters with different techniques.
- Understand the implementation aspects of signal processing algorithms.
- Know the effect of finite word length in signal processing.
- Analyze different power spectrum estimation techniques.

Reference Books:

1. Digital signal processing-sanjit K. Mitra-TMH second edition
2. Discrete Time Signal Processing – Alan V.Oppenheim, Ronald W.Shafer - PHI-1996 1st edition-9th reprint
3 Digital Signal Processing principles, algorithms and Applications – John G.Proakis -PHI –3rd edition-2002
4. Digital Signal Processing – S.Salivahanan, A.Vallavaraj, C. Gnanapriya – TMH - 2nd reprint-2001
5. Theory and Applications of Digital Signal Proceesing-LourensR.Rebinar&Bernold
6. Digital Filter Analysis and Design-Auntonian-TMH

SMART GRID TECHNOLOGIES

(Common to HVE, PSHVE)

(Elective – I)

Perquisites: Basic knowledge on smart concept communication protocols, renewable energy systems and electronic circuits.

Course Educational Objectives:

- To understand concept of smart grid and developments on smart grid.
- To understand smart grid technologies and application of smart grid concept in hybrid electric vehicles etc.
- To have knowledge on smart substations, feeder automation and application for monitoring and protection.
- To have knowledge on micro grids and distributed energy systems.
- To know power quality aspects in smart grid.

UNIT 1

Introduction to Smart Grid: Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid, Concept of Resilient &Self Healing Grid, Present development & International policies on Smart Grid. Case study of Smart Grid.

UNIT 2

Smart Grid Technologies: Part 1: Introduction to Smart Meters, Real Time Prizing, Smart Appliances, Automatic Meter Reading(AMR), Outage Management System(OMS), Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation, Phase Shifting Transformers.

UNIT 3

Smart Grid Technologies: Part 2: Smart Substations, Substation Automation, Feeder Automation. Geographic Information System(GIS), Intelligent Electronic Devices(IED) & their application for monitoring & protection, Smart storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage, Wide Area Measurement System(WAMS), Phase Measurement Unit(PMU).

UNIT 4

Microgrids and Distributed Energy Resources: Concept of micro grid, need & applications of microgrid, formation of microgrid, Issues of interconnection, protection & control of microgrid. Plastic & Organic solar cells, Thin film solar cells, Variable speed wind generators, fuelcells, microturbines, Captive power plants, Integration of renewable energy sources.

UNIT 5

Power Quality Management in Smart Grid: Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.

Information and Communication Technology for Smart Grid: Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN).

Course Outcomes:

After completion of the course, students will be able to:

- Understand smart grids and analyse the smart grid policies and developments in smart grids.
- Develop concepts of smart grid technologies in hybrid electrical vehicles etc.
- Understand smart substations, feeder automation, GIS etc.
- Analyse micro grids and distributed generation systems.
- Analyse the effect of power quality in smart grid and to understand latest developments in ICT for smart grid.

Text Books:

1. Ali Keyhani, Mohammad N. Marwali, Min Dai "Integration of Green and Renewable Energy in Electric Power Systems", Wiley publishers.
2. Clark W. Gellings, "The Smart Grid: Enabling Energy Efficiency and Demand Response", CRC Press
3. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama,"Smart Grid: Technology and Applications", Wiley
4. Jean Claude Sabonnadière, NouredineHadjsaïd, "Smart Grids", Wiley Blackwell 19
5. Peter S. Fox Penner, "Smart Power: Climate Changes, the Smart Grid, and the Future of Electric Utilities", Island Press; 1 edition 8 Jun 2010
6. S. Chowdhury, S. P. Chowdhury, P. Crossley, "Microgrids and Active DistributionNetworks." Institution of Engineering and Technology, 30 Jun 2009
7. Stuart Borlase, "Smart Grids (Power Engineering)", CRC Press

Reference Books:

1. Andres Carvallo, John Cooper, "The Advanced Smart Grid: Edge Power Driving Sustainability: 1", Artech House Publishers July 2011
2. James Northcote, Green, Robert G. Wilson "Control and Automation of Electric Power Distribution Systems (Power Engineering)", CRC Press
3. MladenKezunovic, Mark G. Adamiak, Alexander P. Apostolov, Jeffrey George Gilbert "Substation Automation (Power Electronics and Power Systems)", Springer
4. R. C. Dugan, Mark F. McGranghan, Surya Santoso, H. Wayne Beaty, "Electrical Power System Quality", 2nd Edition, McGraw Hill Publication
5. Yang Xiao, "Communication and Networking in Smart Grids", CRC Press

BREAKDOWN PHENOMENON IN ELECTRICAL INSULATION
(Gases, Liquids, Solids and Vacuum)
(ELECTIVE-I)
(Common to HVE, PSHVE)

Prerequisites: Basic physics, conduction phenomena in dielectrics.
Course Educational Objectives:

- Understand the fundamental processes of conduction in gases.
- Ionization and breakdown phenomena in gases.
- Breakdown phenomena in liquid and solid dielectrics.
- Breakdown phenomena in vaccum.

UNIT 1: Fundamentals of Electrical Breakdown Phenomena in Gases:
Review of gas laws-mean free path of a particle-velocity distribution of swarm of molecules-Expression for mean free path (λ)-Distribution of free paths-Bohr's model of an atom .calculation of radius of Bohr's orbit Energy of an electron-Ionization energy of an atom calculation of frequency of emitted radiation.

UNIT 2: Ionization Its Gases:
Methods of ionization in gases-Ionization by collision-types of inelastic collisions – collision cross sections.
Behavior of charged particles in a gas in electric fields of low (E/P)-drift velocity –mobility conditions for low (E/P).
Electrical Breakdown in Uniform Fields:
Voltage-current relationship is gaseous gap (small gaps)-condition for high (E/P)-Townsend's first Ionization coefficient (α) - (α/p) is a function of (E/P)-Experimental determination of (α) – Penning effect

UNIT 3:Self-sustained discharge:
β-process and its limitations cathode process –methods of liberating secondary electrons – Townsend's second ionization coefficient -γ -process . Condition for electric spark breakdown. Secondary emission by gas produced photons – Meta stables-Role of solid contaminants. Electron Attachment, electronegative gases (SF_6etc).
Measurement of 'γ'- Paschen's law –expression for Minimum Breakdown voltage and minimum (Pd_{min}) - limitations of Paschen's law.
Breakdown of long gaps: Streamer Mechanism- Explanation for positive streamer. Estimation of space charge fields (Es) - Anode directed streamer - comparison between Townsend and streamer mechanism. Breakdown in non-uniform fields –corona discharges - difference between DC and AC corona. Effect of polarity on break down of point-plane gaps.

UNIT 4: Breakdown in Solids and Liquid Insulations:
Types of Breakdown: Intrinsic Breakdown – Electronic Breakdown – Streamer Breakdown – Electromechanical Breakdown –Thermal Breakdown -treeing and tracking. Electro – Chemical Breakdown – BD due to thermal discharges.

Breakdown in liquids dielectrics:

Pure and commercial liquids – Breakdown tests – Pre-breakdown currents and breakdown in pure liquids – breakdown in commercial liquids –Suspended particle theory, cavitations and bubble mechanism. Thermal breakdown – Stressed oil – Volume Theory.

UNIT 5: Breakdown in Vacuum Insulation:

Pre-Breakdown currents – Steady currents –Micro discharges-Factors affecting the Breakdown . like electrode separation - electrode conditioning - electrode material –Surface condition surface contamination - electrode area and configurations –effect of electrode temperature – frequency of applied voltage – pressure - recovery strength of vacuum gap. Practical Exchange theory –electron beam Hypothesis – Clump mechanism- transition in breakdown mechanisms – criteria for B.D - effect of solids dielectrics in vacuum and liquids.

Course Outcomes: After completion of this course the students will be able to:

- Understand the fundamental process of conduction in gases.
- Understand ionization and breakdown phenomena in gases.
- Understand breakdown phenomena in liquid and solid dielectrics.
- Understand breakdown phenomena in vaccum.

References Books:

1. Fundamentals of gaseous ionization and plasma electronics by EssamNassar,John Wiley, New York (1974).
2. High voltage & electrical insulation by RavindraArora , John willy and sons.
3. High voltage technology –L.L.Alston -Oxford Press (1968).
4. High voltage Engineering Fundamentals E. Kuffel, W. S. Zaengl,andJ. Kuffel oxford (2002).
5. High voltage Engineering, M.S.Naidu and V.Kamaraju (5th edition) McGraw Hill Publishing Co., New Delhi (2011).

I Year - I Semester	L	P	C
	4	0	3

HIGH VOLTAGE POWER APPARATUS AND DIAGNOSTICS

(Common to HVE, PSHVE)

(Elective-II)

Prerequisites: To know about power transformers, Degree of polymerization, dissolved gas analysis, Fourier Transformer and frequency response analysis of transformers.

Course Educational Objectives:

- To study about components of power transformer, types of insulation material, overvoltage due to lightning impulse & faults.
- To study the measurement of resistivity and capacitance of transformer oil, method of measurement of tan delta and analysis to detect ageing.
- To study the concept of moisture in transformer oil and paper and partial discharges detection methods within transformer volume.
- To study the degree of polymerization and to determine tan delta and capacitance in transformer bushing.
- To Study the concept of Fourier Transformer with regard to configuration of winding, frequency response analysis of transformer winding..

UNIT 1: Introduction to power transformer, important components of power transformer, winding configuration, various types of insulation material, LV and HV bushings, cooling of winding. Reasons of failure of transformer, short circuit, overvoltage due to switching operation, inadequate clearances between various windings, over-voltage due to lightning impulse, over voltage due to fault, high level of partial discharges, inappropriate design, over fluxing.

UNIT 2 : Tan delta, capacitance in transformer winding, method of measurement of tan delta and capacitance in transformer ,Tan delta ,resistivity and capacitance of transformer oil, bushing capacitance ,tan delta and resistivity, on-site measurement, analysis to detect ageing and likely failure

UNIT 3: Moisture in transformer oil and paper, ageing effect of paper, insulation resistance, Method of measurement of polarization, polarization value, method of moisture reduction, winding resistance, Influence with regard to life of transformer. Partial Discharges in transformer, causes of partial discharges, concept of partial discharges, acoustic method of measurement of partial discharges, discharges in oil, discharges in paper, method of reduction of partial discharges, analysis and detection of partial discharge sites within transformer volume.

UNIT 4 : Degree of polymerization (DP) of transformer paper, effect of DP on life of transformer, effect of transformer temperature on degree of polymerization, furfural content in oil insulation, inter – relationship between degree of polymerization and furfural content, reduction of degree of polymerization in transformer paper. Dissolved gas analysis in transformer oil, various gas product in transformer oil, tolerable level of gases in transformer onload , detection of important gases in transformer, causes of various gases, likely reason of gases with reference to high temperature and partial discharges.

UNIT 5: Fourier Transform and frequency response analysis of transformer winding, concept of Fourier Transformer with regard to configuration of winding, low, medium and high frequency comparison of frequency response of LV , HV and tapping winding, concept of winding movement on the basis of frequency comparison, turn failure.

Course Outcomes:
After completion of this course the students will be able to

- learn power transformer, types of insulation material.
- the measurement of tan delta and capacitance of transformer oil.
- know the concept of moisture in transformer oil and paper and partial discharges.
- know degree of polymerization.
- know concept of Fourier Transformer and frequency response analysis of transformer winding.

Text Book:

1. Transformer, Bharat Heavy Electricals Limited (Bhopal), Second edition 2003,First Edition 1987 Tata Mc.Graw-hill Publishing Company Ltd. Mc.Graw –Hill officePage 1- 602

Reference book:

1 Seminar on fault finding and life assessment of power transformers Proceedings 25- 26 April2008 New Delhi, Organized by Central Board of Irrigation and Power, New Delhi in association with Omicron India.
2. Transformer Engineering, Blue mend boission, Wiley international publication.

COLLISION PHENOMENA IN PLASAMA SCIENCE

(Common to HVE, PSHVE)

(Elective-II)

Prerequisites: Introduction to plasma physics and quantum physics

Course Educational Objectives: student will be exposed to

- Plasmas and their characterizations
- Charged particle motion in electromagnetic fields.
- Electron Avalanche mechanisms.

UNIT 1 : Ionization, Deionization and Electron Emission :Ionization and plasma conductivity, Production of charged particles, Ionization by cosmic rays, Thermal ionization. The free path, excited states, metastable states.Diffusion, Recombination, Negative ions.Photoelectric emission, Thermionic emission, Field emission.

UNIT 2 : Behavior of charged particles in a gas in electric fields of low E/P and high E/P, Definition and significance of mobility, Forces between ions and molecules, Diffusion under low fields, Electron drift velocity.

UNIT 3 : What is high E/P?, Coefficient of ionization by electron collision, evaluation of $\propto$, electron avalanche, effect of the cathode, Ionization coefficient in alternating fields.
The Self-Sustaining Discharge Breakdown Mechanisms: Ionization by positive-ion collision, Cathode processes, space-charge field of an avalanche. Critical avalanche size,

UNIT 4: Townsend mechanism and its limitations, Streamer formation. The transition between the breakdown mechanisms, The effect of electron attachment.
Partial Breakdown and Breakdown Under Alternating Fields: Electron current, positive-ion current, total current, characteristic time, effect of space charge, Anode coronas, Cathode coronas.

UNIT 5: The Glow and Plasma: General description, The cathode zone, Negative glow and Faraday dark space, positive column, Anode region, other effects.
Definition of plasma, Debye length, scope of known plasmas, Plasma oscillations, high-temperature plasmas, Plasma diagnostics.

Course Outcomes: After completion of this course the students will be able to

- Understand the collision phenomena in different materials.
- Transition from Streamer to Townsend mechanisms of breakdown.
- Electric glow discharge and plasma glow discharge.

Reference Book:

1. Fundamentals of Gaseous Ionization And Plasma Electronics by Essam Nasser, John Willey & Sons, Printed in America, 1971.

ADVANCED EM FIELDS
(Common to HVE, PSHVE)
(Elective-II)

Prerequisites: To know the elements of Electromagnetic and electro static field theory along with the behavior of conductors in an electric field.

Course Educational Objectives:

- To know the analytical calculations of field with space charges electric stress and equation of continuity.
- To know the electric field inside a dielectric material, energy density in a static electric field.
- To know the numerical methods for calculating electrical fields, statically dynamically induced e.m.f. calculations of transmission lines conductors to ground.

UNIT – 1: Electrostatics:
Electrostatic Fields – Coulomb's Law – Electric Field Intensity (EFI) – EFI due to a line and a surface charge – Work done in moving a point charge in an electrostatic field – Electric Potential – Properties of potential function – Potential gradient – Gauss's law – Application of Gauss's Law – Maxwell's first law, div (D)=ρv – Laplace's and Poisson's equations – Solution of Laplace's equation in one variable

UNIT – 2 :Electric fields-1
Introduction, Analytical calculation of space-charge-free fields, simple geometries, transmission conductors to ground, fields in multidielectric media, experimental analogs for space-space-charge-free fields, electrolytic tank, semi conducting paper analog, resistive-mesh analog.,

UNIT – 3 Electric fields-2
Analytical Calculations of Fields With Space Charges, Numerical Computation of Fields With Space Charges, Finite Element Technique, Finite Element Technique Combined With The Method Of Characteristics, Charge-Simulation Technique Combined With The Method Of Residues, Electric Stress Control And Optimization, Electric Stress Control, Electric Stress Optimization

UNIT – 4 : Conductors & Dielectrics :
Behavior of conductors in an electric field – Conductors and Insulators – Electric field inside a dielectric material – polarization – Dielectric – Conductor and Dielectric – Dielectric boundary conditions – Energy stored and energy density in a static electric field – Current density – conduction and Convection current densities – Ohm's law in point form – Equation of continuity

UNIT – 5: Force in Magnetic fields &Time Varying Fields:
Magnetic force - Moving charges in a Magnetic field – Lorentz force equation — a differential current loop as a magnetic dipole ,Time varying fields – Faraday's laws of electromagnetic induction – Its integral and point forms ,Statically and Dynamically induced EMFs -Modification of Maxwell's equations for time varying fields – Displacement current

Course Outcomes:

After completion of this course the students will be able to:

- know about analysis of electrostatic fields and properties of potential gradients.
- knows about the dielectric boundary conditions and electric stress control and optimization and time varying fields.

Text Books:

1. "Engineering Electromagnetic" by William H. Hayt& John. A. Buck McGraw-Hill Companies, 7th Editon.2005.
2. "Electromagnetics" by J. D Kraus Mc.Graw-Hill Inc. 4th edition 1992.

Reference Books:

1. Field Theory ", Gangadhar, Khanna Publishers.
2. Elements of Electromagnetic field theory ", Sadiku, Oxford Publ.
3. "Electromagnetics" by J P Tewari.
4. "Introduction to E-Magnetics" by CR Paul and S.A. Nasar, McGraw-Hill Publications
5. "Introduction to Electro Dynamics" by D J Griffiths, Prentice-Hall of India Pvt.Ltd, 2nd editon
6. "Electromagnetics" by Plonsy and Collin
7. "Engineering Electro magnetics" by Nathan Ida, Springer (India) Pvt. Ltd.2nd Edition.

I Year - I Semester	L	P	C
	0	4	2

HIGH VOLTAGE LABORATORY

(Common to HVE, PSHVE)

Course Educational Objectives:

To understand the operation of high voltage generation and testing the various insulators.

Any 10 of the following experiments are to be conducted

List of Experiments:

1. Millivolt drop test and Tong tester calibration
2. Breakdown characteristics of sphere-sphere gap
3. Measurement of Leakage current and breakdown voltage of pin insulator
4. Breakdown test of transformer oil
5. Breakdown characteristics of rod-rod gap
6. Measurement of Leakage current and insulation resistance of polypropylene scale
7. Measurement of Leakage current and insulation resistance of polypropylene rope
8. Breakdown characteristics of plane-rod-gap
9. Measurement of leakage current and breakdown voltage of suspension insulator
10. Breakdown characteristics of point-sphere gap
11. Measurement of tan delta and dielectric constant
12. Power frequency testing of HV transformer
13. Power frequency testing of HV Bushing
14. Power frequency testing of HV Cable.

Course Outcomes:

After the Completion of lab will understand testing procedures of various insulators.

I Year - II Semester	L	P	C
	4	0	3

HIGH VOLTAGE TESTING TECHNIQUES

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE)

Prerequisites: Basics of high voltage engineering.

Course Educational Objectives:

- To understand Nondestructive testing methods.
- To understand Commercial and technical testing of different HV power applications.

UNIT 1 : Non Destructive Testing Techniques : Measurement of DC Resistivity – Dielectric loss and dielectric constant of insulating materials – Schering bridge method – Transformer ratio arm bridge for high voltage and high current applications – null detectors.

UNIT 2 : High Voltage Testing of Power Apparatus : Need for testing standards – Standards for porcelain/Glass insulators-Classification of porcelain/glass insulator tests – Tests for cap and pin porcelain/Glass insulators.

UNIT 3 : High voltage AC testing methods-Power frequency tests-Over voltage tests on insulators, Isolators, Circuit Breakers and power cables. Artificial Contamination Tests : Contamination flashover phenomena-Contamination Severity-Artificial contamination tests-Laboratory Testing versus in-Service Performance-Case study.

UNIT 4 : Impulse Testing : Impulse testing of transformers, insulators, Surge diverters, Bushings, cables, circuit breakers.

UNIT 5 : Partial Discharge Measurement : PD equivalent model-PD currents-PD measuring circuits-Straight and balanced detectors-Location and estimation of PD in power apparatus-PD measurement by non electrical methods-Calibration of PD detectors. RIV Measurements : Radio Interference – RIV – Measurement of RI and RIV in laboratories and in field. Different test arrangements and their limitations.

Course Outcomes:

After completion of this course the students will be able to:

- Understand different testing procedures on electrical a) Insulating materials b) Insulation Systems. c) Power apparatus.
- Learn the different testing techniques adopted on electrical power apparatus.

Reference Books :

1. High Voltage Engineering – by E.KUFFEL and W.S.ZAENGL, Pergamon press, Oxford 1984.
2. High Voltage Engineering – by M.S.Naidu and V.Kamaraju, Tata McGraw Hill Publishing Company Limited, New Delhi – 2001.
3. Discharge Detection in H.V. Equipment – by KREUGER, F.H. Haywood London – 1964.
4. Hyltencavallius. N. High voltage laboratory planning EnileHaefely&Co. Ltd. Based Switzerland 1988
5. Ryan H.M. and Whiskand: design and operation perspective of British UHV Lab IEE pre 133 H.V. Testing Techniques Halfly

I Year - II Semester	L	P	C
	4	0	3

EHVAC TRANSMISSION

(Common to HVE,PSHVE)

Prerequisites: Transmission line parameters and properties, Corona etc.

Course Educational Objectives:

- To calculate the transmission line parameters.
- To calculate the field effects on EHV and UHV AC lines.
- To have knowledge of corona, RI and audible noise in EHV and UHV lines.
- To have knowledge of voltage control and compensation problems in EHV and UHV transmission systems.

UNIT-1: E.H.V. A.C. Transmission , line trends and preliminary aspects ,standard transmission voltages – power handling capacities and line losses – mechanical aspects. Calculation of line resistance and inductance: resistance of conductors, temperature rise of conductor and current carrying capacity. Properties of bundled conductors and geometric mean radius of bundle, inductance of two conductor lines and multi conductor lines, Maxwell's coefficient matrix. Line capacitance calculation.capacitance of two conductor line, and capacitance of multi conductor lines, potential coefficients for bundled conductor lines, sequence inductances and capacitances and diagonalization.

UNIT-2 : Calculation of electro static field of AC lines - Effect of high electrostatic field on biological organisms and human beings. Surface voltage Gradient on conductors, surface gradient on two conductor bundle and cosine law, maximum surface voltage gradient of bundle with more than 3 sub conductors, Mangolt formula.

UNIT-3 : Corona : Corona in EHV lines – corona loss formulae – attenuation of traveling waves due to corona – Audio noise due to corona, its generation, characteristics and limits, measurement of audio noise.

UNIT-4 : Power Frequency voltage control : Problems at power frequency, generalized constants, No load voltage conditions and charging currents, voltage control using synchronous condenser, cascade connection of components : Shunt and series compensation, sub synchronous resonance in series – capacitor compensated lines

UNIT -5 : Static reactive compensating systems : Introduction, SVC schemes, Harmonics injected into network by TCR, design of filters for suppressing harmonics injected into the system.

Course Outcomes: After completion of the course, the student will be able to:

- Calculate the transmission line parameters.
- Calculate the field effects on EHV and UHV AC lines.
- Determine the corona, RI and audible noise in EHV and UHV lines.
- Analyze voltage control and compensation problems in EHV and UHV transmission systems.

Reference Books :

1. Extra High Voltage AC Transmission Engineering – Rakesh Das Begamudre, Wiley Eastern ltd., New Delhi – 1987.
2. EHV Transmission line reference book – Edison Electric Institute (GEC) 1986.

I Year - II Semester

L	P	C
4	0	3

SURGE PHENOMENON AND INSULATIONCO-ORDINATION

(Common to HVE, PSHVE)

Prerequisites: Basic concepts oftravelling wave techniques and their applications in electrical power systems, lightening and switching over voltages, insulation co-ordination in power systems.

Course Educational Objectives:

- To understand travelling wave phenomenon in transmission systems.
- To know different types of over voltages that originate in power systems.
- To know Insulation gradation for different electrical power apparatus and coordination in insulation systems.

UNIT 1 : Traveling Waves : Transmission line equation, attenuation and distortion point-Typical cases.
Reflection of traveling waves: Behaviors of waves at a transaction point-Typical case. Travelling waves on multi conductor systems

UNIT 2 : Successive Reflections : Reflection lattice, Effect of insulation capacitance. Standing waves and natural frequencies of transmission lines-Transient response of lines and systems with distributed parameters.

UNIT 3 : Lightning Phenomena and over voltage in power systems. Mechanism of the lightning stroke – Mathematical model of the lightning stroke. Over voltages produced in power systems due to lightning – Over voltage due to faults in the system and switching surges. General principles of lightning protection – Tower – Footing resistance – Insulation withstand voltages and impulse flashover characteristics of protective gaps.

UNIT 4 : Surge Voltage distribution in transformer windings initial and final distribution characteristics : Protection of windings against over voltages. protection of transmission lines, transformers and rotating machines against over voltages. Use of rod gaps and lightning arresters protective characteristics.Selection of the lightning arresters.

UNIT 5 : Insulation coordination lightning surge and switching surge characteristics of insulation structures. Geo-metric gap factors test procedures, correlation between insulation for protective levels. Protective devices Znoarresters,vale type-etc, protective tubes

Course Outcomes: After completion of this course the students will be able to:

- Understand line concepts of travelling waves and their behavior in transmission systems.
- Understand lighting phenomena and over voltages in power systems.
- Understand the behavior of the transformer when surge voltages are induced in the windings.
- Understand the insulation coordination between different protecting and protective devices in the power system.

Reference Books :

1. Traveling waves of Transmission systems – by LV Bewley. Dover publications Inc., New York (1963).
2. Lewis, w.w., protection of transmission lines and systems against lightining, dover publications, Inc., New York (1965).
3. Diesendorf.W, Insulation Co-ordination ELBS in H.V. Electrical Power Systems , Butter worth publications, London, (1974).
4. Rakesh Das Begmudre,E.H.V. Transmission Engineering: Wielly Eastern Ltd., New Delhi, (1986).

I Year - II Semester	L	P	C
	4	0	3

ADVANCED POWER SYSTEM PROTECTION

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE, PE&PS)

Prerequisites: Concepts of Power Electronics, Electronic circuits, STLD and basics of Relays and protection.

Course Educational Objectives:

- To learn about classification and operation of static relays.
- To understand the basic principles and application of comparators.
- To learn about static version of different types of relays.
- To understand about numerical protection.

UNIT 1 : Static Relays classification and Tools : Comparison of Static with Electromagnetic Relays, Basic classification, Level detectors and Amplitude and phase Comparators – Duality – Basic Tools – Schmitt Trigger Circuit, Multivibrators, Square wave Generation – Polarity detector – Zero crossing detector – Thyristor and UJT Triggering Circuits. Phase sequence Filters – Speed and reliability of static relays.

UNIT 2 : Amplitude and Phase Comparators (2 Input) : Generalized equations for Amplitude and Phase comparison – Derivation of different characteristics of relays – Rectifier Bridge circulating and opposed voltage type amplitude comparators – Averaging & phase splitting type amplitude comparators – Principle of sampling comparators.

Phase Comparison : Block Spike and phase Splitting Techniques – Transistor Integrating type, phase comparison, Rectifier Bridge Type Comparison – Vector product devices.

UNIT 3 : Static over current (OC) relays – Instantaneous, Definite time, Inverse time OC Relays, static distance relays, static directional relays, static differential relays, measurement of sequence impedances in distance relays, multi input comparators, elliptic & hyperbolic characteristics, switched distance schemes, Impedance characteristics during Faults and Power Swings,

UNIT 4 : PILOT Relaying schemes: Wire pilot protection: circulating current scheme – balanced voltage scheme – translay scheme – half wave comparison scheme - carrier current protection: phase comparison type – carrier aided distance protection – operational comparison of transfer trip and blocking schemes – optical fibre channels.

UNIT 5 : Microprocessor based relays andNumerical Protection: Introduction – over current relays – impedance relay – directional relay – reactance relay.

Numerical Protection: Introduction - numerical relay - numerical relaying algorithms - mann-morrison technique - Differential equation technique and discrete fourier transform technique - numerical over current protection - numerical distance protection.

Course Outcomes:

After completion of the course, the student will be able to:

- Know the classifications and applications of static relays.
- Understand the application of comparators.
- Understand the static version of different types of relays.
- Understand the numerical protection techniques.

Reference Books :

1. Power System Protection with Static Relays – by TSM Rao ,TMH.
2. Protective Relaying Vol-II Warrington, Springer .
3. Art & Science of Protective Relaying - C R Mason, Wiley.
4. Power System Stability KimbarkVol-II, Wiley.
5. Power system protection & switchgear by Badri Ram & D N viswakarma. TMH.
6. Electrical Power System Protection –C.Christopoulos and A.Wright- Springer
7. Protection & Switchgear –BhaveshBhalaja,R.PMaheshwari, NileshG.Chothani-Oxford publisher

I Year - II Semester

	L	P	C
	4	0	3

PARTIAL DISCHARGES IN HV EQUIPMENT

(Common to, HVE, PSHVE)

(Elective-III)

Prerequisites: Knowledge in High Voltage Equipment.

Course Educational Objectives:

- To know about Partial Discharges, necessity of detection of partial discharge
- To know about effects of partial discharges on insulating systems.
- To know different detection methods used for partial discharges.

UNIT 1 : Types of partial discharges and its occurrence and recurrence and magnitudes : Definition of Partial discharges, inception of internal discharges, Inception of corona discharges.

UNIT 2 : Discharges by electrical treeing. Discharges at AC Voltages, corona discharges, Discharges at D.C. Voltages, discharges at impulse voltages.
Object of discharge detection, Quantities related to the magnitude of discharges, choice of PD as a measure for discharges.

UNIT 3 : Electrical discharge detection & Detection circuits : Basic diagram, amplification of impulses, sensitivity, resolution, observation. Straight detection.
Balanced detection, calibrators, Interferences, choice between straight detection & balance detection, common mode rejection.

UNIT 4 : Location of Partial discharges : Non-electric location, location by separation of electrodes, location with electrical probes. location by traveling waves, PD location in cables & switchgear by traveling waves. Evaluation of discharges: Recognition, mechanisms of deterioration, evaluation, specification.

UNIT 5 : Detection in actual specimen : Detection in capacitors, cables, bushings. Transformers, machine insulation, Gas-insulated switchgear.

Course Outcomes:

After completion of the course, the student will be able to:

- Types of partial discharge that occurs in the insulation systems and in apparatus.
- Detection of discharges using different detection circuits.
- Location of partial discharge in electrical apparatus and systems.

Reference Book :

1. Partial Discharges in HV Equipment by F..Kruguer, Butterworths& Co., Publications Ltd., 1989.
2. *Partial Discharges in Electrical Power Apparatus.* by Dieter Konig, Y. *NarayanaRao-* VDE-Verlag publisher

GAS INSULATED SYSTEMS AND SUBSTATIONS

(Common to, HVE, PSHVE)

(Elective-III)

Prerequisites: Conduction and Breakdown in gases, and substation.

Course Educational Objectives:

- To Study and learn about SF_6 gas properties and application in electrical apparatus.
- To Study and learn about Details of SF_6 Substation.
- To Study and learn about Testing of G.I.S.

UNIT 1

Introduction to GIS and Properties of SF6:

Characteristics of GIS, Introduction to SF_6, Physical Properties, Chemical Properties, Electrical Properties, Specifications of SF_6 Gas for GIS Applications, Handling of SF_6 Gas Before Use, Safe Handling of SF_6 Gas in Electrical Equipment, Equipment for Handling the SF_6 Gas, SF_6 and Environment.

UNIT 2

Layout of GIS Stations:

Advantages of GIS Stations, Comparison With Air Insulated Substations, Economics of GIS,User Requirements for GIS,Main Features of a GIS,General Arrangement of a GIS,Planning and Installation,Components of a GIS station.

UNIT 3

Design and Construction of GIS Stations:

Introduction,Ratings of GIS Components,DesignFeatures,Estimation of Different types of Electrical Stresses,Design Aspects of GIS Components,Insulation Design for GIS,Thermal Considerations in the Design of GIS,Effect of Very Fast Transient over voltages(VFTO)on the GIS Design,Insulation Coordination in GIS ,GIS Grounding Systems,Gas handling and Monitoring System Design.

UNIT 4

Testing of GIS

Introduction, Various Tests on GIS,Design Approach for Manufacturing and Type Tests,Quality Assurance in Manufacturing,Shipping and Erection,On-Site Testing of GIS, Dielectric Tests, commonly used On-site Test Methods,Experience during On-Site Testing,Condition Monitoring and Diagnostic Methods.

UNIT 5

GIS Diagnostics and Fast Transient Phenomena in GIS

Introduction,Characteristics of imperfections inInsulation,Insulation Diagnostic Methods,PDMeasurement,UHFMethod,Disconnector Switching in Relation to Very Fast Transients,Origin of VFTO, Propagation and Mechanism of VFTO,VFTO Characteristics,Effect of VFTO,Testing of GIS for VFTO.

Course Outcomes:

After completion of the course, the student will be able to:

- Know the Properties of SF_6
- Construction of G.I.S Substations
- Transient Phenomenon and testing of G.I.S

Text Book:

1. M.S.Naidu,"Gas Insulated Substations" I.K International publishing house Pvt.Ltd, New Delhi.

Reference Books:

1. O.Kindsen&K.V.Menon, " Future developments trend in GIS Technology" 3rd workshop & conference on EHV Technology, Indian Institute of Science, Bangalore, August 2-4, 1995.
2. V.N.Maller and M.S.Naidu "Advances in High Voltage Insulation & Arc Interruption in SF6 and Vaccum", Pergamon Press, Oxford, 1982.

PULSE POWER ENGINEERING

(Common to, HVE, PSHVE)
(Elective-III)

Prerequisites: Basic concepts of Pulse forming networks and energy storage devices

Course Educational Objectives:

- To know the static and dynamic breakdown strength of dielectric materials and various switches
- To know the energy storage device like Marx generator, inductive energy storage, rotor and homo polar generators, fly wheels.
- To know the design of pulse forming networks in transmission lines and power and voltage adding.

UNIT1: **Static and Dynamic Breakdown Strength of dielectric Materials**

Introduction-Gases-static breakdown-pulsed breakdown-spark formation-liquids-basic electrical Process-steamer breakdown-practical considerations-solids-General observations-charge Transport, injection and Breakdown-statistical Interpretation of breakdown Strength Measurements

UNIT2: Energy Storage

Pulse Discharge Capacitors-Marx Generators-classical Marx generators-LC Marx Generator-Basic Pulsed-Power Energy Transfer Stage-inductive energy storage-power and voltage multiplication-rotors and homo polar Generators

UNIT3: **Switches**

Closing switches-gas switches-semi conductor closing switches-magnetic switches-summary-opening switches-fuses-mechanical interrupters-superconducting opening switches-plasma opening switches-plasma flow switches-semiconductor opening switches

UNIT 4: Pulse forming networks:

Transmission lines-terminations and junctions-transmission lines with losses-the finite transmission line as a circuit element-production of pulses with lossless transmission lines-RLC networks-circuit simulation with LEITER

Power and Voltage Adding: Adding of Power-Voltage Adding-voltage adding by transit-time Isolation- voltage adding by Inductive Isolation-Blumlein Generators-Cumulative Pulse Lines

UNIT5: Examples of Pulsed-power Generators:

Single-pulse generators: KALIF-PBFA 2 and the Z-Machine- HERMES III

Repetitive Generators: RHEPP and Generators with opening switches

Course Outcomes:
After completion of the course, student will able to know

- Various energy storage devices, repetitive generators and cumulative pulse lines.
- Pulse forming networks and their applications.
- Pulse power generators.

Reference Books:

1. Pulsed Power Engineering by Professor Dr.HasjoachimBluhm.
2. Explosive Pulsed Power -L. L. Altgilbers, J. Baird, B. Freeman, C. S. Lynch, and S. I. Shkuratov -Imperial College Press.
3. Advances in Pulsed Power Technology, Vol. 1 & 2, Plenum Press.
4. Pulsed Power Systems: Principles and Applications-Dr.HasjoachimBluhm-Springer

I Year - II Semester	L	P	C
	4	0	3

FLEXIBLE AC TRANSMISSION SYSTEMS

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE, PE&PS)

(Elective- IV)

Prerequisites: Concepts on Power Electronics and Power Systems

Course Educational Objectives:

- To study the performance improvements of transmission system with FACTS.
- To study the effect of static shunt compensation.
- To study the effect of static series compensation.
- To study the effect of UPFC.

UNIT 1 : FACTS concepts, Transmission interconnections, power flow in an AC System, loading capability limits, Dynamic stability considerations, importance of controllable parameters, basic types of FACTS controllers, benefits from FACTS controllers.

UNIT 2 : Basic concept of voltage and current source converters, comparison of current source converters with voltage source converters.
Static shunt compensation : Objectives of shunt compensation, midpoint voltage regulation, voltage instability prevention, improvement of transient stability, Power oscillation damping, methods of controllable var generation, variable impedance type static var generators, switching converter type var generators, hybrid var generators.

UNIT 3 :SVC and STATCOM : The regulation and slope transfer function and dynamic performance, transient stability enhancement and power oscillation damping, operating point control and summary of compensation control.

UNIT 4 : Static series compensators : Concept of series capacitive compensation, improvement of transient stability, power oscillation damping, functional requirements. GTO thyristor controlled series capacitor (GSC), thyristor switched series capacitor (TSSC), and thyristor controlled series capacitor (TCSC), control schemes for GSC, TSSC and TCSC.

UNIT 5 : Unified Power Flow Controller: Basic operating principle, conventional transmission control capabilities, independent real and reactive power flow control, comparision of the UPFC to series compensators and phase angle regulators.

Course Outcomes:
After completion of the course, the student will be able to :

- Able to know the performance improvement of transmission system with FACTS.
- Able to get the knowledge of effect of static shunt and series compensation.
- Able to know the effect of UPFC.
- Able to determine an appropriate FACTS device for different types of applications.

ReferenceBooks :

1. "Understanding FACTS Devices" N.G.Hingorani and L.Guygi, IEEE Press. Indian Edition is available -Standard Publications
2. Sang.Y.Hand John.A.T, "Flexible AC Transmission systems" IEEE Press (2006).
3. HVDC & FACTS Controllers: applications of static converters in power systems- Vijay K.Sood- Springer publishers

POWER SYSTEM DEREGULATION

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE, PE&PS)

(Elective -IV)

Prerequisites: Knowledge onPower systems

Course Educational Objectives:

- To provide in-depth understanding of operation of deregulated electricity market systems.
- To examine typical issues in electricity markets and how these are handled world –wide in various markets.
- To enable students to analyze various types of electricity market operational and control issues using new mathematical models.

UNIT 1

Need and conditions for deregulation. Introduction of Market structure, MarketArchitecture, Spot market, forward markets and settlements.Review ofConcepts marginal cost of generation, least-cost operation, incremental cost of generation. Power System Operation.

UNIT 2

Electricity sector structures and Ownership /management, the forms of Ownership and management.Different structure model like Monopoly model, Purchasing agency model, wholesale competition model, Retail competition model.

UNIT 3

Framework and methods for the analysis of Bilateral and pool markets, LMP based markets, auction models and price formation, price based unit commitment, country practices

UNIT 4

Transmission network and market power. Power wheeling transactions and marginal costing, transmission costing.Congestion management methods- market splitting, counter-trading; Effect of congestion on LMPs- country practices

UNIT 5

Ancillary Services and System Security in Deregulation. Classifications and definitions, AS management in various markets- country practices. Technical, economic, & regulatory issues involved in the deregulation of the power industry.

Corse Outcomes:

After completion of the course, the student will be able to:

- Understand of operation of deregulated electricity market systems
- Typical issues in electricity markets
- To analyze various types of electricity market operational and control issues using new mathematical models.

Reference Books:

1. Power System Economics: Designing markets for electricity - S. Stoft
2. Power generation, operation and control, -J. Wood and B. F. Wollenberg
3. Operation of restructured power systems - K. Bhattacharya, M.H.J. Bollen and J.E. Daalder
4. Market operations in electric power systems - M. Shahidehpour, H. Yaminand Z. Li
5. Fundamentals of power system economics - S. Kirschen and G. Strbac
6. Optimization principles: Practical Applications to the Operation and Markets of the Electric Power Industry - N. S. Rau
7. Competition and Choice in Electricity - Sally Hunt and Graham Shuttleworth

REACTIVE POWER COMPENSATION & MANAGEMENT

(Common to HVE, PSHVE, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

(Elective- IV)

Prerequisites: Brief idea of power system analysis, electric traction systems and Arc furnaces

Course Educational Objectives:

- To know the basic objectives of reactive power compensation.
- To know the types of compensation and their behavior.
- To know the mathematical modeling of reactive power compensating devices.
- To know the reactive power compensation has to be done at distribution side.
- To know the role of reactive power compensation at electric traction systems and Arc furnaces.

UNIT -1:Load Compensation

Objectives and specifications – reactive power characteristics – inductive and capacitive approximate biasing – Load compensator as a voltage regulator – phase balancing and power factor correction of unsymmetrical loads- examples.

UNIT -2: Reactive power compensation in transmission system:

Steady state -Uncompensated line – types of compensation – Passive shunt and series and dynamic shunt compensation – examples

Transient state - Characteristic time periods – passive shunt compensation – static compensations- series capacitor compensation –compensation using synchronous condensers – examples

UNIT -3:Reactive power coordination:

Objective – Mathematical modeling – Operation planning – transmission benefits – Basic concepts of quality of power supply – disturbances- steady –state variations – effects of under voltages – frequency – Harmonics, radio frequency and electromagnetic interferences

UNIT -4:Distribution side Reactive power Management:

System losses –loss reduction methods – examples – Reactive power planning – objectives – Economics Planning capacitor placement – retrofitting of capacitor banks

User side reactive power management:

KVAR requirements for domestic appliances – Purpose of using capacitors – selection of capacitors – deciding factors – types of available capacitor, characteristics and Limitations

UNIT-5: Reactive power management in electric traction systems and are furnaces:

Typical layout of traction systems – reactive power control requirements – distribution transformers- Electric arc furnaces – basic operations- furnaces transformer –filter requirements – remedial measures –power factor of an arc furnace

Course Outcomes: After completion of the course the student will be able to

- Learn various load compensations.
- Obtain the mathematical model of reactive power compensating devices.
- Get application of reactive power compensation in electrical traction & arc furnaces.

Reference Books:

1. Reactive power control in Electric power systems by T.J.E.Miller, John Wiley and sons, 1982
2. Reactive power Management by D.M.Tagare,Tata McGraw Hill,2004

I Year - II Semester	L	P	C
	0	4	2

SIMULATION LABORATORY

(Common to HVE, PSHVE)

Course Educational Objectives: To understand the modeling of various aspects of Power System analysis and develop the MATLAB programming.

List of Experiments:

1. Formation of Y- Bus by Direct-Inspection Method.
2. Load Flow Solution Using Gauss Siedel Method
3. Load Flow Solution Using Newton Raphson Method
4. Load Flow Solution UsingFast Decoupled Method
5. Formation of Z-Bus by Z-bus building algorithm
6. Symmetrical Fault analysis using Z-bus
7. Unsymmetrical Fault analysis using Z-bus
8. Economic Load Dispatch with & without transmission losses
9. Transient Stability Analysis Using Point By Point Method
10. Load Frequency Control of Single Area Control& Two Area Control system with and without controllers.

Course Outcomes: After the completion of the lab they will verify the theoretical concepts of various aspects of Power System analysis.

II Year - III Semester	**L**	**P**	**C**
	0	**0**	**2**

COMPREHENSIVE VIVA-VOCE

II Year - III Semester	L	P	C
	0	0	2

SEMINAR - I

II Year - III Semester	**L**	**P**	**C**
	0	**0**	**16**

PROJECT WORK PART - I

II Year - IV Semester	L	P	C
	0	0	2

SEMINAR - II

	L	P	C
II Year - IV Semester	0	0	18

PROJECT WORK PART - II

ACADEMIC REGULATIONS & COURSE STRUCTURE

For

POWER ELECTRONICS (PE)
POWER AND INDUSTRIAL DRIVES (P&ID)
POWER ELECTRONICS AND ELECTRICALDRIVES (PE &ED)
POWER ELECTRONICS AND DRIVES (PE&D)
POWER ELECTRONICS AND SYSTEMS (PE&S)
ELECTRICAL MACHINES AND DRIVES (EM&D)

(Applicable for batches admitted from 2016-2017)

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY: KAKINADA
KAKINADA - 533 003, Andhra Pradesh, India

I Semester

S. No.	Subject	L	P	Credits
1	Electrical Machine Modeling & Analysis	4	--	3
2	Analysis of Power Electronic Converters	4	--	3
3	Power Electronic Control of DC Drives	4	--	3
4	Flexible AC Transmission Systems	4	--	3
5	**Elective – I** i. Modern Control Theory ii. Power Quality ii. Optimization Techniques	4	--	3
6	**Elective – II** i. Energy Auditing, Conservation and Management ii. Artificial Intelligence Techniques iii. HVDC Transmission	4	--	3
7	Simulation Laboratory	--	4	2
Total Credits				**20**

II Semester

S. No.	Subject	L	P	Credits
1	Switched Mode Power Conversion	4	--	3
2	Power Electronic Control of AC Drives	4	--	3
3	Digital Controllers	4	--	3
4	Custom Power devices	4	--	3
5	**Elective – III** i. Renewable Energy Systems ii. Reactive Power Compensation & Management iii. Electrical Distribution Systems	4	--	3
6	**Elective – IV** i. Smart Grid Technologies ii. Special Machines iii Programmable Logic Controllers & Applications	4	--	3
7	Power Converters & Drives Laboratory	--	4	2
Total Credits				**20**

III Semester

S. No.	Subject	L	P	Credits
1	Comprehensive Viva-Voce	**--**	**--**	2
2	Seminar – I	--	--	2
3	Project Work Part - I	--	--	16
Total Credits				**20**

IV Semester

S. No.	Subject	L	P	Credits
1	Seminar – II	--	--	2
2	Project Work Part - II	--	--	18
Total Credits				**20**

I Year - I Semester	L	P	C
	4	0	3

ELECTRICAL MACHINE MODELING & ANALYSIS
(Common to PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

Prerequisites: Electrical machines & Special machines.

Course Educational Objectives:

- To know the concepts of generalized theory of electrical machines.
- To represent the DC and AC machines as Basic Two Pole machine.
- To model the electrical machines with voltage, current, torque and speed equations.
- To investigate the steady state and transient behaviour of the electrical machines.
- To understand the dynamic behaviour of the AC machines.

UNIT – 1: Basic concepts of Modeling

Basic Two-pole Machine representation of Commutator machines, 3-phase synchronous machine with and without damper bars and 3-phase induction machine, Kron's primitive Machine-voltage, current and Torque equations.

UNIT – II: DC Machine Modeling

Mathematical model of separately excited D.C motor – Steady State analysis-Transient State analysis-Sudden application of Inertia Load-Transfer function of Separately excited D.C Motor-Mathematical model of D.C Series motor, Shunt motor-Linearization Techniques for small perturbations

UNIT- III: Reference frame theory&Modeling of single phase Induction Machines

Linear transformation-Phase transformation - three phase to two phase transformation (abc to $\alpha\beta0$) and two phase to three phase transformation $\alpha\beta0$ to abc - -Power equivalence-Mathematical modeling of single phase induction machines.

UNIT – IV: Modeling of three phase Induction Machine

Generalized model in arbitrary reference frame-Electromagnetic torque-Derivation of commonly used Induction machine models- Stator reference frame model-Rotor reference frame model-Synchronously rotating reference frame model-state space model with flux linkages as variables

UNIT –V: Modeling of Synchronous Machine& Special machines

Synchronous machine inductances –voltage equations in the rotor's dq0 reference frame-electromagnetic torque-current in terms of flux linkages-three synchronous machine model-modeling of PM Synchronous motor, modeling of BLDC motor, modeling of Switched Reluctance motor

Course Outcomes:

After completion of this course the students will be able to:

- Apply knowledge of behaviour of DC motors to model and analyse for different applications.
- Analyse the characteristics of different types of DC motors to design suitable controllers
- Apply the knowledge of reference frame theory for AC machines to model the induction andSynchronous machines.
- Evaluate the steady state and transient behaviour of induction and synchronous machines toPropose the suitability of drives for different industrial applications
- Analyse the 2-Phase induction machines using voltage and torque equations to differentiate the behaviour and to propose their applications in real world.

Reference Books:

1. Electric Motor Drives - Modeling, Analysis& control -R.Krishnan- Pearson Publications- 1st edition -2002
2. Analysis of Electrical Machinery and Drive systems – P.C.Krause, Oleg Wasynczuk, Scott D.Sudhoff – Second Edition-IEEE Press.
3. Dynamic simulation of Electric machinery using Matlab / Simulink –CheeMunOng- Prentice Hall
4. P.S.Bhimbra,'' Generalised theory of Electrical Machines''-Fifth edition,Khanna publishers.

I Year - I Semester	L	P	C
	4	0	3

ANALYSIS OF POWER ELECTRONIC CONVERTERS
(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

Prerequisites: Power switching devices, characteristics & Commutation techniques.

Course Educational Objectives:

- To study the operation of AC voltage converters and controllers.
- To study the necessity requirement of power factor correction for converter circuits.
- To study the operation of inverters with and without PWM controller.
- To study the operation of different types of multilevel inverters.

UNIT-I AC voltage Controllers

Single Phase AC Voltage Controllers with PWM control only –synchronous tap changers - Three Phase AC Voltage controllers-Analysis of Controllers with star and delta connected resistive, resistive –inductive loads-Effects of source and load inductances–Application- numerical problems.

UNIT –II AC-DC converters

Single phase full and half Converters with inductive load– Power factor improvements: Extinction angle control-symmetrical angle control - single phase sinusoidal PWM-Single phase series converters- numerical problems - Three Phase full and half Converter with inductive load–harmonic analysis -Power factor improvements-three phase PWM-twelve pulse converters-numerical problems

UNIT-III Power Factor Correction Converters

Single-phase single stage boost power factor corrected rectifier, power circuit principle of operation, and steady state- analysis, three phase boost PFC converter

UNIT –IV PWM Inverters

single phase full bridge inverters - sinusoidal PWM – modified PWM – phase displacement Control – Trapezoidal, staircase, stepped, harmonic injection and delta modulation – numerical problems - Three-Phase Inverters- Sinusoidal PWM- 60^0 PWM- Third Harmonic PWM- Space Vector Modulation- Comparison of PWM Techniques-current source inverters-Variable dc link inverter - numerical problems

UNIT V: Multi level inverters

Multilevel Concept, Types of Multilevel Inverters- Diode-Clamped Multilevel Inverter, Features of Diode-Clamped Inverter, Improved Diode-Clamped Inverter- Flying-Capacitors Multilevel Inverter-Features of Flying-Capacitors Inverter- Cascaded Multilevel Inverter- Principle of Operation- Features of Cascaded Inverter- Switching Device Currents-DC-Link Capacitor Voltage Balancing- Features of Multilevel Inverters- Comparisons of Multilevel Converters

Course Outcomes: After completion of this course the students will be able to:

- Analyze the operation of phase controlled converters and AC voltage converters.
- Analyze the requirements of power factor correction in converter circuits.
- Describe and analyse the operation of 3-phase inverters with and without PWM techniques.
- Describe principles of operation and features of multilevel inverters.

Reference books:

1. Power Electronics-Md.H.Rashid –Pearson Education Third Edition- First IndianReprint-2008
2. Power Electronics- Ned Mohan, Tore M.Undelan and William P.Robbins –John Wiley& Sons -2nd Edition.
3. Power Electronics – Lander –Ed.2009
4. Modern power Electronics and AC Drives – B.K.Bose
5. Power Converter Circuits – William Shepherd & Li Zhang-Yes Dee Publishing PvtLtd.

I Year - I Semester	L	P	C
	4	0	3

POWER ELECTRONIC CONTROL OF DC DRIVES
(Common to PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

Prerequisites: Power Electronics & DC Machines.

Course Educational Objectives:

- To study the operation of Phase Controlled Converters based DC drives in four quadrants.
- To study modeling concepts of AC – DC converters fed drive components.
- To study the operation of DC- DC converter fed DC drives.
- To study the operation of closed loop control based DC-DC converters fed DC drives.

UNIT-I Introduction on single phase convertor fed DC motor drive:
Basic power electronic drive system, components, stability of power electronic drive, single phase full-convertor and half-convertor fed dc drives for continuous and discontinuous mode of operation. Four quadrant operation of drive using dual convertor.

UNIT-II Three phase AC-DC convertor fed DC motor drive:
Three phase full-convertor and half-convertor fed dc drives for continuous and discontinuous mode of operation. Four quadrant operation of drive using three phase dual convertor. Pulsating torque

UNIT-III Modeling of AC-DC convertor fed DC drive components & design of controller:
Transfer function of Dc motor and load, convertor, current and speed controllers, current and speed feedback elements. Design of current controller and speed controller. Closed loop two quadrant DC motor drive, closed loop four quadrant DC motor drive, introduction to simulation of DC motor drive.

UNIT-IV DC-DC convertor fed DC motor drive:
Four quadrant DC-DC convertor fed dc motor drive, steady state analysis of DC-DC convertor dc motor drive, pulsating torques.

UNIT-V Closed loop operation of DC-DC convertor fed dc motor drive:
Design of current controller, design of speed controller, modeling of current and speed controller, introduction to simulation of speed controlled dc motor drive.

Course Outcomes:

After completion of this course the students will be able to:

- Analyse single phase and three phase converter fed DC drives.
- Analyse the two quadrants and four quadrant controls of DC motor drives.
- Develop the mathematical models of DC drive components.
- Analyse the four quadrant and closed loop control of DC-DC converter fed DC drive.

Reference Books:

1. Electrical Motor Drives Modeling, Analysis and Control – R. Krishna, Prentice Hall India.
2. Power Semiconductor Controlled Drives – G.K. Dubey.Prentice Hall India.
3. Power Electronics and Motor control – Shepherd, Hulley, Liang-II Edition, Cambridge University Press.
4. Power electronic circuits, devices and applications – M.H.Rashid – PHI.

I Year - I Semester	L	P	C
	4	0	3

FLEXIBLE AC TRANSMISSION SYSTEMS
(Common to PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

Prerequisites: Concepts on Power Electronics and Power Systems

Course Educational Objectives:

- To study the performance improvements of transmission system with FACTS.
- To study the effect of static shunt compensation.
- To study the effect of static series compensation.
- To study the effect of UPFC.

UNIT 1 : FACTS concepts, Transmission interconnections, power flow in an AC System, loading capability limits, Dynamic stability considerations, importance of controllable parameters, basic types of FACTS controllers, benefits from FACTS controllers.

UNIT 2 : Basic concept of voltage and current source converters, comparison of current source converters with voltage source converters.

Static shunt compensation : Objectives of shunt compensation, midpoint voltage regulation, voltage instability prevention, improvement of transient stability, Power oscillation damping, methods of controllable var generation, variable impedance type static var generators, switching converter type var generators, hybrid var generators.

UNIT 3 :SVC and STATCOM : The regulation and slope transfer function and dynamic performance, transient stability enhancement and power oscillation damping, operating point control and summary of compensation control.

UNIT 4 : Static series compensators : Concept of series capacitive compensation, improvement of transient stability, power oscillation damping, functional requirements. GTO thyristor controlled series capacitor (GSC), thyristor switched series capacitor (TSSC), and thyristor controlled series capacitor (TCSC), control schemes for GSC, TSSC and TCSC.

UNIT 5 : Unified Power Flow Controller: Basic operating principle, conventional transmission control capabilities, independent real and reactive power flow control, comparison of the UPFC to series compensators and phase angle regulators.

Course Outcomes:
After completion of the course, the student will be able to:

- Know the performance improvement of transmission system with FACTS.
- Get the knowledge of effect of static shunt and series compensation.
- Know the effect of UPFC.
- Determine an appropriate FACTS device for different types of applications.

Reference Books :

1. "Understanding FACTS Devices" N.G.Hingorani and L.Guygi, IEEE Press. Indian Edition is available:--Standard Publications
2. Sang.Y.Hand John.A.T, "Flexible AC Transmission systems" IEEE Press (2006).
3. HVDC & FACTS Controllers: applications of static converters in power systems- Vijay K.Sood- Springer publishers

I Year - I Semester

L	P	C
4	0	3

MODERN CONTROL THEORY
(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES,

PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

(Elective-I)

Prerequisites: Control Systems, differential equations.

Course Educational Objectives:

- To facilitate the evolution of state variable approach for the analysis of control systems.
- To examine the importance of controllability and observability in modern control engineering.
- To enable students to analyze various types of nonlinearities & construction of trajectories using describing functions and phase plane analysis.
- To study the analysis of stability and instability of continuous time invariant system

UNIT –1: State Variable Analysis
The concept of state – State Equations for Dynamic systems – State diagram - Linear Continuous time model for physical systems – Existence and Uniqueness of Solutions to Continuous – Time State Equations – Solutions – Linear Time Invariant Continuous – Time State Equations – State transition matrix and it's properties

UNIT – 2: State Variable Techniques
General concept of Controllability - General concept of Observability Controllability tests for Continuous &Time Invariant systems - Observability tests for Continuous &Time Invariant systems - Controllability and Observability of state model in Jordan Canonical form - Controllability and Observability Canonical forms of State model – State feedback controller design through pole assignment.

UNIT – 3: Non Linear Systems – I
Introduction – Non Linear Systems – Types of Non – Linearities – Saturation – Dead – Zone – Backlash – Jump Phenomenon etc; - Singular Points – Introduction to Linearization of nonlinear systems, properties of Non Linear Systems – Describing function – describing function analysis of nonlinear systems- Stability analysis of Non – Linear systems through describing functions.

UNIT – 4: Non Linear Systems – II
Introduction to phase – plane analysis, Method of Isoclines for Constructing Trajectories, singular points, phase – plane analysis of nonlinear control systems.

UNIT – 5: Stability Analysis
Stability in the sense of Lyapunov, Lyapunov's stability and Lyapunov's instability theorems – Stability Analysis of the Linear Continuous time invariant systems by Lyapunov second method – Generation of Lyapunov functions – Variable gradient method – Krasooviski's method.

Course Outcomes:

After completion of this course the students will be able to:

- Understanding the state variable approach is suitable for higher order.
- To analyze the concepts of controllability and observability.
- To analyze the various non-linearities through describing functions and phase plane analysis.
- Typical issues of stability and instability of continuous time invariant systems.

Reference Books :

1. Modern Control System Theory by M. Gopal – New Age International – 1984
2. Modern Control Engineering by Ogata. K – Prentice Hall – 1997
3. Nonlinear systems, Hassan K. Klalil, Prentice Hall, 1996
4. Modern control systems, Richard C. Dorf and Robert H. Bishop, 11^{th} Edition, Pearson Edu, India, 2009

POWER QUALITY
(Common to PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

(Elective I)

Prerequisites: Knowledge on electric circuit analysis, power systems and power electronics.

Course Educational Objectives:

- To understand significance of power quality and power quality parameters.
- To know types of transient over voltages and protection of transient voltages.
- To understand harmonics, their effects, harmonic indices and harmonic minimization techniques.
- To understand long duration voltage variation and flicker
- To know power quality aspects in distributed generation.

UNIT-1 Introduction
Overview of Power Quality - Concern about the Power Quality - General Classes of Power Quality Problems – Transients -Long-Duration Voltage Variations - Short-Duration Voltage Variations - Voltage Unbalance - Waveform Distortion - Voltage fluctuation - Power Frequency Variations - Power Quality Terms - Voltage Sags and Interruptions - Sources of Sags and Interruptions – Nonlinear loads.

UNIT-2 Transient Over Voltages
Source of Transient Over Voltages - Principles of Over Voltage Protection - Devices for Over Voltage Protection - Utility Capacitor Switching Transients - Utility Lightning Protection - Load Switching Transient Problems - Computer Tools for Transient Analysis

UNIT-3 Harmonic Distortion and solutions
Voltage vs. Current Distortion - Harmonics vs. Transients - Power System Quantities under Nonsinusoidal Conditions - Harmonic Indices – Sources of harmonics - Locating Sources of Harmonics – System Response Characteristics - Effects of Harmonic Distortion – Interharmonics - Harmonic Solutions Harmonic Distortion Evaluation - Devices for Controlling Harmonic Distortion - Harmonic Filter Design - Standards on Harmonics

UNIT- 4 Long Duration Voltage Variations
Principles of Regulating the Voltage - Device for Voltage Regulation - Utility Voltage Regulator Application - Capacitor for Voltage Regulation - End-user Capacitor Application - Regulating Utility Voltage with Distributed Resources – Flicker

UNIT-5 Distributed Generation and Power Quality
Resurgence of Distributed Generation - DG Technologies - Interface to the Utility System - Power Quality Issues - Operating Conflicts - DG on Low Voltage Distribution Networks - Interconnection standards - Wiring and Grounding - Typical Wiring and Grounding Problems - Solution to Wiring and grounding Problems

Course Outcomes:

After completion of this course the students will be able to:

- Have the knowledge on causes of power quality, power quality parameters.
- Understand sources of transient over voltages and providing protection to transient over voltages.
- Understand effects of harmonics, sources of harmonics and harmonic minimization.
- Analyze long duration voltage variations and regulation of voltage variations.
- Describe power quality aspects in distributed generation and develop solutions to wiring and grounding problems.

Reference Books :

1. Electrical Power Systems Quality, Dugan R C, McGranaghan M F, Santoso S, and Beaty H W, Second Edition, McGraw-Hill, 2002.
2. Power Quality Primer, Kennedy B W, First Edition, McGraw-Hill, 2000.
3. Understanding Power Quality Problems: Voltage Sags and Interruptions, Bollen M H J, First Edition, IEEE Press; 2000.
4. Power System Harmonics, Arrillaga J and Watson N R, Second Edition, John Wiley & Sons, 2003.
5. Electric Power Quality control Techniques, W. E. Kazibwe and M. H. Sendaula, Van Nostrad Reinhold, New York.
6. Power Quality c.shankaran, CRC Press, 2001
7. Harmonics and Power Systems –Franciso C.DE LA Rosa-CRC Press (Taylor & Francis)
8. Power Quality in Power systems and Electrical Machines-EwaldF.fuchs, Mohammad A.S. Masoum-Elsevier

OPTIMIZATION TECHNIQUES
(Common to PE, P&ID, PE&ED, PE&D, PE&S, EM&D, PE&PS)

(Elective I)

Prerequisites: Concepts of engineering mathematics and mathematical methods.

Course Educational Objectives:

- To define an objective function and constraint functions in terms of design variables, and then state the optimization problem.
- To state single variable and multi variable optimization problems, without and with constraints.
- To explain linear programming technique to an optimization problem, define slack and surplus variables, by using Simplex method.
- To study and explain nonlinear programming techniques, unconstrained or constrained, and define exterior and interior penalty functions for optimization problems.
- To introduce evolutionary programming techniques.
- To introduce basic principles of Genetic Algorithms and Partial Swarm Optimization methods.

UNIT – I:
Introduction and Classical Optimization Techniques:
Statement of an Optimization problem – design vector – design constraints – constraint surface – objective function – objective function surfaces – classification of Optimization problems.
Single variable Optimization – multi variable Optimization without constraints – necessary and sufficient conditions for minimum/maximum – multivariable Optimization with equality constraints.Solution by method of Lagrange multipliers – multivariable Optimization with inequality constraints – Kuhn – Tucker conditions.

UNIT – II:
Linear Programming
Standard form of a linear programming problem – geometry of linear programming problems – definitions and theorems – solution of a system of linear simultaneous equations – pivotal reduction of a general system of equations – motivation to the simplex method – simplex algorithm - Duality in Linear Programming – Dual Simplex method.

UNIT – III:
Nonlinear Programming:
Unconstrained cases - One – dimensional minimization methods: Classification, Fibonacci method and Quadratic interpolation method - Univariate method, Powell's method and steepest descent method.
Constrained cases - Characteristics of a constrained problem, Classification, Basic approach of Penalty Function method; Basic approaches of Interior and Exterior penalty function methods. Introduction to convex Programming Problem.

UNIT – IV:

Introduction to Evolutionary Methods:

Evolutionary programming methods - Introduction to Genetic Algorithms (GA)– Control parameters –Number of generation, population size, selection, reproduction, crossover and mutation – Operator selection criteria – Simple mapping of objective function to fitness function – constraints – Genetic algorithm steps – Stopping criteria –Simple examples.

UNIT – V:

Introduction to Swarm Intelligence Systems:

Swarm intelligence programming methods - Basic Partial Swarm Optimization – Method – Characteristic features of PSO procedure of the global version – Parameters of PSO (Simple PSO algorithm – Operators selection criteria – Fitness function constraints) – Comparison with other evolutionary techniques – Engineering applications of PSO.

Course Outcomes:

After completion of this course the students will be able to:

- State and formulate the optimization problem, without and with constraints, by using design variables from an engineering design problem.
- Apply classical optimization techniques to minimize or maximize a multi-variable objective function, without or with constraints, and arrive at an optimal solution.
- Formulate a mathematical model and apply linear programming technique by using Simplex method. Also extend the concept of dual Simplex method for optimal solutions.
- Apply gradient and non-gradient methods to nonlinear optimization problems and use interior or exterior penalty functions for the constraints to derive the optimal solutions.
- Able to apply Genetic algorithms for simple electrical problems.
- Able to solve practical problems using PSO.

Text Books

1. "Engineering optimization: Theory and practice"-by S. S.Rao, New Age International (P) Limited, 3rd edition, 1998.
2. Soft Computing with Matlab Programming by N.P.Padhy&S.P.Simson, Oxford University Press – 2015

Reference Books:

1. **"**Optimization methods in operations Research and Systems Analysis" by K.V.Mital and C.Mohan, New Age International (P) Limited, Publishers, 3rd edition, 1996.
2. Genetic Algorithms in search, optimization, and Machine Learning by David E.Goldberg,ISBN:978-81-7758-829-3, Pearsonby Dorling Kindersley (India) Pvt. Ltd.
3. "Operations Research: An Introduction" by H.A.Taha, PHI pvt. Ltd., 6th edition.
4. Linear Programming by G.Hadley.,Narosa Publishers.

I Year - I Semester	L	P	C
	4	0	3

ENERGY AUDITING, CONSERVATION&MANAGEMENT
(Common to PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

(Elective II)

Perquisites: Concepts of utilization of electrical energy, electrical machines and electrical measurements.

Course Educational Objectives:

- To learn principle of energy audit as well as management for industries and utilities and buildings.
- To study the energy efficient motors and lighting.
- To learn power factor improvement methods and operation of different energy instruments.
- To compute depreciation methods of equipment for energy saving.

UNIT I: Basic Principles of Energy Audit
Energy audit- definitions, concept , types of audit, energy index, cost index ,pie charts, Sankey diagrams, load profiles, Energy conservation schemes- Energy audit of industries- energy saving potential, energy audit of process industry, thermal power station, building energy audit

UNIT II: Energy Management –I
Principles of energy management, organizing energy management program, initiating, planning, controlling, promoting, monitoring, reporting. Energy manger, Qualities and functions, language, Questionnaire – check list for top management

UNIT III: Energy Efficient Motors and Lighting
Energy efficient motors , factors affecting efficiency, loss distribution , constructional details , characteristics – variable speed , variable duty cycle systems, RMS hp- voltage variation-voltage unbalance- over motoring- motor energy audit. Good lighting system design and practice, lighting control, lighting energy audit

UNIT IV: Power Factor Improvement and energy instruments
Power factor – methods of improvement , location of capacitors , Power factor with non-linear loads, effect of harmonics on p.f. , p.f motor controllers – Energy Instruments- watt meter, data loggers, thermocouples, pyrometers, lux meters, tongue testers ,application of PLC's

UNIT V: Economic Aspects and their computation
Economics Analysis-Depreciation Methods, time value of money, rate of return, present worth method, replacement analysis, lifecycle costing analysis – Energy efficient motors. Calculation of simple payback method, net present worth method- Power factor correction, lighting – Applications of life cycle costing analysis, return on investment.

Course Outcomes: After completion of this course the students will be able to:

- Perform energy audit in different organizations.
- Recommend energy efficient motors and design good lighting system.
- Understand advantages to improve the power factor.
- Evaluate the depreciation of equipment.

Reference Books:

1. Energy management by W.R. Murphy & G. Mckay Butter worth, Heinemann publications.
2. Energy efficient electric motors by John .C. Andreas, Marcel Dekker Inc Ltd-2nd edition, 1995-
3. Energy management by Paul o' Callaghan, Mc-graw Hill Book company-1st edition, 1998
4. Energy management hand book by W.C.Turner, John wiley and sons
5. Energy management and good lighting practice : fuel efficiency- booklet12-EEO

ARTIFICIAL INTELLIGENCE TECHNIQUES
(Common to PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)
(Elective-II)

Prerequisites: Basic knowledge on human biological systems, concept of optimization and electrical engineering.

Course Educational Objectives:

- To have knowledge on concept of neural network.
- To know different types of neural networks and training algorithms.
- To understand the concept of genetic algorithm and its application in optimization.
- To have the knowledge on fuzzy logic and design of fuzzy logic controllers.
- To know the applications of AI Techniques in power electronics and DC drives.

UNIT – 1: Introduction to Neural Networks
Introduction, Humans and Computers, Biological Neural Networks, Historical development of neural network, Terminology and Topology, Biological and artificial neuron models, Basic learning laws.

UNIT- 2:Feed Forward Neural Networks
Introduction, Perceptron models: Discrete, continuous and multi-category, Training algorithms: Discrete and Continuous Perceptron Networks, Perceptron convergence theorem, Limitations and applications of the Perceptron model, Generalized delta learning rule, Feedforward recall and error back propagation training-Radial basis function algorithms-Hope field networks

UNIT -3: Genetic algorithms &Modelling-introduction-encoding-fitness function-reproduction operators-genetic operators-cross over and mutation-generational cycle-convergence of genetic algorithm

UNIT – 4:Classical and Fuzzy Sets
Introduction to classical sets - properties, operations and relations; Fuzzy sets, membership, Uncertainty, operations, properties, fuzzy relations, cardinalities, membership functions.
Fuzzy Logic System Components-Fuzzification, Membership value assignment, development of rule base and decision making system, defuzzification to crisp sets, defuzzification methods.

UNIT-5: Application of AI Techniques: Design of PI controller for speed control of DC motor using neural networks and fuzzy logic-PWM Controllers -Selected harmonic elimination PWM-Space vector PWM using neural network.

Course Outcomes: After completion of this course, students will be able to

- Understand neural networks and analyze different types of neural networks.
- Design training algorithms for neural networks.
- Develop algorithms using genetic algorithm for optimization.
- Analyze and designfuzzy logic systems.
- Apply AI Techniques in power electronics and DC drives.

Reference Books:

3. Neural Networks, Fuzzy logic, Genetic algorithms: synthesis and applications by Rajasekharan andPai – PHI Publication.
4. Introduction to Artificial Neural Systems - Jacek M. Zuarda, Jaico Publishing House, 1997.
5. Modern Power Electronics and AC Drives –B.K.Bose-Pearson Publications
6. Genetic Algorithms- David E Goldberg. Pearson publications.

HVDC TRANSMISSION
(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE, PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

(Elective II)

Prerequisites: Knowledge on Power Electronics, Power Systems and High Voltage Engineering

Course Educational Objectives:

- To learn various schemes of HVDC transmission.
- To learn about the basic HVDC transmission equipment.
- To learn the control of HVDC systems.
- To be exposed to the interaction between HVAC and HVDC system.
- To be exposed to the various protection schemes of HVDC engineering.

UNIT -1: Limitation of EHV AC Transmission, Advantages of HVDC Technical economical reliability aspects. HVDC Transmission: General considerations, Power Handling Capabilities of HVDC Lines, Basic Conversion principles, static converter configuration. Types of HVDC links-Apparatus and its purpose.

UNIT-2: Static Power Converters: 6-pulse bridge circuit and 12-pulse converters, converter station and Terminal equipment, commutation process, Rectifier and inverter operation, equivalent circuit for converter – special features of converter transformers. Comparison of the perform of diametrical connection with 6-pulse bridge circuit

UNIT-3 : Control of HVDC Converters and systems : constant current, constant extinction angle and constant Ignition angle control. Individual phase control and equidistant firing angle control, DC power flow control. Factors responsible for generation of Harmonics voltage and current harmonics effect of variation of α and μ. Filters Harmonic elimination.

UNIT-4 : Interaction between HV AC and DC systems – Voltage interaction, Harmonic instability problems and DC power modulation. Development of DC circuit Breakers, Multi-terminal DC links and systems; series, parallel and series parallel systems, their operation and control.

UNIT -5 : Transient over voltages in HV DC systems : Over voltages due to disturbances on DC side, over voltages due to DC and AC side line faults. Converter faults and protection in HVDC Systems: Converter faults, over current protection - valve group, and DC line protection, circuit breakers. Over voltage protection of converters, surge arresters.

Course Outcomes:

After completion of this course the students will be able to:

- Understand the various schemes of HVDC transmission.
- Understand the basic HVDC transmission equipment.
- Understand the control of HVDC systems.
- Understand the interaction between HVAC and HVDC system.
- Understand the various protection schemes of HVDC engineering.

Reference Books:

1. S Kamakshaih and V Kamaraju:HVDC Transmission- MG hill.
2. K.R.Padiyar : High Voltage Direct current Transmission, Wiley Eastern Ltd., New Delhi – 1992.
3. E.W. Kimbark : Direct current Transmission, Wiley Inter Science – New York.
4. J.Arillaga : H.V.D.C.Transmission Peter Peregrinus ltd., London UK 1983
5. Vijay K Sood :HVDC and FACTS controllers:Applications of static converters in power systems by, Kluwer Academic Press.

I Year - I Semester	L	P	C
	0	4	2

SIMULATION LABORATORY
(Common to PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

Prerequisites: Concepts of Power Electronics & Closed loop control.

Course Educational Objectives:

- To understand the characteristics of Thyristor MOSFET & IGBT by simulation.
- To understand the operation of power electronics converters by simulation.
- To understand how to implement PWM techniques in simulation.
- To understand and analyse the speed control of AC motors in open and closed loop in simulation.

Any 10 of the following experiments are to be conducted.

List of experiments:

1. Switching characteristics simulation analysis of Thyristor, MOSFET,IGBT .
2. Simulation analysis of single phase full converter using R-L load, R-L-E load with and without LC Filter.
3. Simulation analysis of Three phase full converter using R-L-E Load.
4. Simulation analysis of single phase AC Voltage controller with PWM control for RL load.
5. Simulation analysis of three phase AC Voltage controller using RL load.
6. Simulation analysis of single phase inverter with sinusoidal PWM control forR& RL – loads.
7. Simulation analysis of Three phase inverter with Sinusoidal PWM control for R& RL - Loads.
8. Simulation analysis of Buck, Boost& Buck-Boost DC-DC converters.
9. Simulation analysis of three phase converter fed DC motor.
10. Development of mathematical model and simulation analysis of induction machines under balanced and symmetrical conditions for the following
    a. dq model in synchronous reference frame
    b. dq model in stator reference frame
    c. dq model in rotor reference frame
11. Simulation analysis of Volts/Hz closed-loop speed control of an induction motor drive.
12. Simulation analysis of Open-loop Volts/Hz control of a synchronous motor drive.
13. Simulation analysis of Speed control of a permanent magnet synchronous motor.
14. Simulation analysis of Capacitor-start capacitor-run single-phase induction motor.

COURSE OUTCOMES: After completion of this course the students will be able to:

- Analyse the characteristics of power semiconductor devices in simulation.
- Analyse the operation of various power electronic converters in simulation.
- Analyse and implementing the speed controlling techniques for AC machines in simulation.
- Analyse and implementing PWM techniques in simulation.

I Year - II Semester

L	P	C
4	0	3

SWITCHED MODE POWER CONVERSION
(Common to PE, P&ID, PE&ED, PE&D, PE&S, EM&D, PE&PS)

Perquisites: Concepts of electrical circuit analysis and power electronics.

Course Educational Objectives:

- To understand the control operation of non-sinusoidal DC-DC converters.
- To understand the basic operation of resonant converters.
- To understand the control operation of isolated DC-DC converters.
- To understand the control schemes of DC-DC converters and designing of magnetic components.
- To understand the modeling and control design of switch mode conversion based on linearization.
- To understand how to analyse the switch mode converters using small-signal analysis.

UNIT-I: Non-isolated switch mode converters:
Control of DC-DC converters, Buck converters, Boost converters, Buck-Boost converter, CUK Converter, Converter realization with nonideal components.

UNIT-II: Resonant converters:
Basic resonant circuit concepts, series resonant circuits, parallel resonant circuits, zero current switching Quasi-resonant buck converter, zero current switching Quasi-resonant boost converter, zero voltage switching Quasi-resonant buck converter, zero voltage switching Quasi-resonant boost converter

UNIT-III: Isolated switch-mode converters:
Forwarded converter, fly back converter, Push-pull converter, half-bridge converter, full bridge converter

UNIT-IV: Control schemes of switching converters:
Voltage-mode control, Current-mode control, control scheme for resonant converters, proportional integral controller.
Magnetic design consideration: Transformers design, DC inductor and capacitor design.

UNIT-V: Modeling& Control design based on linearization:
Formulation of averaged models for buck and boost converters average circuits models, small – signal analysis and linearization.
Control design based on linearization: Transfer function of converters, control design, large signal issues in voltage-mode & current-mode control.

Course Outcomes:
After completion of this course the students will be able to:

- Analyse the control operation of non-isolated switch mode converters.
- Analyse the operation of resonant converters and soft switching.
- Analyse the operation of isolated switch mode converters.
- Analyse the control schemes for resonant converters and design of magnetic components.
- Analyse the design of non-isolated switch mode converters based on linearization.
- Analyse the switch mode converters with small signal analysis.

Reference Books:

1. Power Electronics – IssaBataresh, Jhonwilley publications,2004
2. Power switching converters-simonang, alejandro olive, CRC Press (Taylor &franicsgroup).
3. Elements of Power Electronics – Philip T. Krein, Oxford University press.
4. Power Electronics: converters Applications & Design – Mohan, Undeland, Robbins-Wiley publications

I Year - II Semester

	L	P	C
	4	**0**	**3**

POWER ELECTRONIC CONTROL OF AC DRIVES
(Common to PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

Perquisites: Concepts of power electronics, electrical machines and closed loopcontrol.

Course Educational Objectives:

- To analyse the VSI fed induction motor drive.
- To study the performance of different types of BLDC motor drives.
- To study different traction drives.
- To know the operation and control of switched reluctance motor & stepper motor.

UNIT-I: 3-phase induction motor drives – Part 1

Analysis of IM fed from non-sinusoidal supply, harmonic equivalent circuit, transient analysis – starting and plugging; variable frequency control, torque-slip relation, starting torque and braking torque, closed-loop VSI fed IM drive. Slip-ring IM control, closed-loop speed control with static rotor resistance, closed-loop speed control by using slip power recovery scheme.

UNIT-II: 3-phase induction motor drives – Part 2

Concept of space vector, vector control of IM: direct or feed-back vector control, flux vector estimation, indirect or feed forward vector control, vector control of line side PWM converter, stator flux oriented vector control, vector control of converter fed inverter drive.

UNIT-III: Synchronous motor and BLDC motor drives

Variable frequency control of synchronous motor, closed-loop control of inverter fed synchronous motor drive. Permanent magnet synchronous motor drive. BLDC motor drives, VSI fed BLDC motor drives, back emf, phase current and torque waveforms, control of BLDC motors with sensors, sensor-less control of BLDC motors

UNIT-IV: Traction drives

Motors employed in railway traction and road-vehicles, control of railway traction dc motors using ac-dc converters, control of railway traction ac motors using ac-dc and dc-ac converters, power electronic control circuits of electric vehicles and hybrid electric vehicles

UNIT-V: Switched reluctance and stepper motor drives

Switched reluctance motor operation and control: modes of operation, converter circuits closed-loop speed control. Stepper motor characteristics drive circuits for uni-polar and bipolar stepper motors.

Course Outcomes: After completion of this course the students will be able to:

- Explain operation of induction motor and analyse speed control of AC drivesbyVSIfed drives.
- Understand vector control of induction motors.
- Understand operation of traction drives.
- Analyse control schemes to synchronous motor drives.
- Understand control of switched reluctance motor & stepper motor.

Reference Books:

1. "Electric motor drives, modeling, analysis and control", R. Krishnan, PHI Publishers
2. "Control of electric drives", W. Leonhard, Springer Verilog
3. "Vector control of AC machines", ArindamGhosh, Gerard Ledwich
4. "Power Electronics: Converters,Application and design" ,Mohan, Undeland and Robbins, Wiley Publications.
5. "Urban transport and hybrid electric vehicles", Edited by SerefSoylu, Published online, 18 Aug 2010. Available:http://www.intechopen.com/books/urban-transport-and-……..
6. "Power control of AC motors", J.M.D. Murphy and F. G. Turnbul
7. "Power semiconductor drives", G. K. Dubey, Printice Hall International
8. "Fundamentals of electric drives", G. K. Dubey, Narosa Publishing House

I Year - II Semester	L	P	C
	4	0	3

DIGITAL CONTROLLERS
(Common to PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

Prerequisites: Basic concepts of switching theory & logic design and fundamentals of micro controllers.

Course Educational Objectives:

- To understand the architecture of PIC micro controller.
- To understand the architecture of DSP processor and their interface.
- To understand how to write the program for DSP processor using assembly Programming.
- To understand the different types of FPGA and configurations.
- To understand the basics of programming in Xilinx.

UNIT- I
PIC MICROCONTROLLERS

PIC Microcontrollers: Overview and Features, PIC 16C6X/7X, FSR(File Selection Register) [Indirect Data Memory Address Pointer], PIC Reset Actions, PIC Oscillator Connections, PIC Memory Organizations, PIC PIC 16C6X/7X Instructions, Addressing Modes, I/O Ports, Interrupts in PIC 16C61/71, PIC 16C61/71 Timers, PIC 16C71 Analog-to-Digital Converter (ADC)

UNIT - II
INTRODUCTION TO DSP

Introduction to the C2xx DSP core and code generation, The components of the C2xx DSP core, Mapping external devices to the C2xx core , peripherals and Peripheral Interface , System configuration registers , Memory , Types of Physical Memory , memory Addressing Modes , Assembly Programming using C2xx DSP, Instruction Set, Software Tools.

UNIT - III
I/O & CONTROL REGISTERS

Pin Multiplexing (MUX) and General Purpose I/O Overview, Multiplexing and General Purpose I/O Control Registers .Introduction to Interrupts, Interrupt Hierarchy, Interrupt Control Registers, Initializing and Servicing Interrupts in Software.

UNIT - IV
ADC & EVENT MANAGER

ADC Overview , Operation of the ADC in the DSP , Overview of the Event manager (EV) , Event Manager Interrupts , General Purpose (GP) Timers , Compare UNITs, Capture UNITs And Quadrature Enclosed Pulse (QEP) Circuitry , General Event Manager Information

UNIT - V
FPGA

Introduction to Field Programmable Gate Arrays – CPLD Vs FPGA – Types of FPGA , Xilinx XC3000 series , Configurable logic Blocks (CLB), Input/Output Block (IOB) – Programmable Interconnect Point (PIP) – Xilinx 4000 series – HDL programming – overview of Spartan 3E and Virtex II pro FPGA boards- case study.

Course Outcomes:
After completion of this course the students will be able to:

- Know the interfacing circuits for input and output to PIC micro controllers and DSP processors.
- Know how to write ALP for DSP processors.
- Design PWM controls for power electronic circuits using FPGA.

Reference Books:

1. Microcontrollers-Theory and Applications by Ajay V Deshmukh, McGraw Hills
2. Microcontrollers by Kennith J ayala, Thomson publishers
3. Microprocessor and Microcontrollers by Prof C.R.Sarma.
4. Hamid.A.Toliyat and Steven G.Campbell"DSP Based Electro Mechanical Motion Control " CRC Press New York , 2004.
5. XC 3000 series datasheets (version 3.1). Xilinx,Inc.,USA, 1998.
6. Wayne Wolf," FPGA based system design ", Prentice hall, 2004

I Year - II Semester

L	P	C
4	0	3

CUSTOM POWER DEVICES
(Common to PE, P&ID, PE&ED, PE&D, PE&S, EM&D, PE&PS)

Prerequisites: Concept of power electronics and concept of reactive power compensation.

Course Educational Objectives:

- To understand the various power quality issues and their effects on the distribution circuits.
- To understand principle of working of various custom power devices.
- To understand the other custom power devices and their applications to power system.

UNIT I-Introduction

Custom Power and Custom Power Devices - power quality variations in distribution circuits – Voltage Sags, Swells, and Interruptions - System Faults – Over voltages and Under voltages - Voltage Flicker - Harmonic Distortion - Voltage Notching - Transient Disturbances - Characteristics of Voltage Sags.

UNIT II-Overview of Custom Power Devices

Reactive Power and Harmonic Compensation Devices - Compensation Devices for Voltage Sags and Momentary Interruptions - Backup Energy Supply Devices - Battery UPS – Super Conducting Magnetic Energy Storage systems - Flywheel – Voltage Source Converter - Multi-level converters.

UNIT III-Reactive Power and Harmonic Compensation Devices

Var control devices - Static Var Compensator – Topologies - Direct Connected Static Var Compensation for Distribution Systems – Static Series Compensator - Static Shunt Compensator (DSTATCOM) - Interaction with Distribution Equipment and System - Installation Considerations.

UNIT IV- High-Speed Source Transfer Switches, Solid State Limiting, And Breaking Devices:

Source Transfer Switch - Static Source Transfer Switch (SSTS),- Hybrid source transfer switch – High-speed mechanical source transfer switch - Solid state current limiter - Solid state breaker .

UNIT V-Application of Custom Power Devices in Power Systems

P-Q theory – Control of P and Q – Dynamic Voltage Restorer (DVR) – Operation and control – Interline Power Flow Controller (IPFC) – Operation and control – Unified Power Quality Conditioner (UPQC) – Operation and control. Recent custom power devices.

Course Outcomes:

After completion of this course the students will be able to:

- Analyse the effect of various power quality issues in distribution system and their mitigation principles.
- Describe the operation of custom power devices for reactive power & harmonic compensation.
- Analyse high speed transfer switches.
- Analyse the operation and control of custom power devices in power system applications.

Text Books

1. Guidebook on Custom Power Devices, Technical Report, Published by EPRI, Nov 2000
2. Power Quality Enhancement Using Custom Power Devices – Power Electronics and Power Systems, Gerard Ledwich, ArindamGhosh, Kluwer Academic Publishers, 2002.

Reference Books:

1. Power Quality, C. Shankaran, CRC Press, 2001
2. Instantaneous power theory and application to power conditioning, H. Akagiet.al., IEEE Press, 2007.
3. Custom Power Devices - An Introduction, ArindamGhosh and Gerard Ledwich, Springer, 2002
4. A Review of Compensating Type Custom Power Devices for Power Quality Improvement, Yash Pal et.al., Joint International Conference on Power System Technology and IEEE Power India Conference, 2008. POWERCON 2008.

I Year - II Semester	L	P	C
	4	0	3

RENEWABLE ENERGY SYSTEMS
(Common to PE, P&ID, PE&ED, PE&D, PE&S, EM&D)
(Elective-III)

Prerequisites: Basic idea of non-conventional energy sources.

Course Educational Objectives:

- To learn basic principle of renewable energy sources.
- To adoption of alternative energy sources for power generation.
- To learn alternative energy sources not based on sun.
- To the adoption and inter connection of renewable and alternative energy sources to grid.

UNIT-1

Solar Energy - Availability - Solar radiation data and measurement - Estimation of average solar radiation - Solar water heater types - Heat balance – Flat plate collector efficiency – Efficiency of heat removal - Thermo siphon flow calculation - Forced circulation calculation - Evacuated collectors - Basics of solar concentrators Solar Energy Applications - Solar air heaters – Solar Chimney - Crop driers - Passive solar system - Active solar systems - Water desalination - Output from solar still – Principle of solar ponds.

UNIT-2

Wind Energy – Nature of wind – Characteristics – Variation with height and time – Power in wind –Aerodynamics of Wind turbine – Momentum theory – Basics of aerodynamics – Aero foils and their characteristics – HAWT – Blade element theory – Prandtl's lifting line theory (prescribed wake analysis) VAWT aerodynamics – Wind turbine loads – Aerodynamic loads in steady operation – Yawed operation and tower shadow. Wind Energy Conversion System – Siting – Rotor selection – Annual energy output – Horizontal axis wind turbine (HAWT) – Vertical axis wind turbine (VAWT) – Rotor design considerations – Number of blades – Solidity - Blade profile – Upwind/Downwind – Yaw system – Tower – Braking system - Synchronous and asynchronous generators and loads – Integration of wind energy converters to electrical networks – Inverters – Control system – Requirement and strategies – Noise Applications of wind energy

UNIT-3

Biomass energy - Bio fuel classification – Examples of thermo chemical, Pyrolysis, biochemical and agrochemical systems – Energy farming – Direct combustion for heat – Process heat and electricity – Ethanol production and use – Anaerobic digestion for biogas – Different digesters – Digester sizing – Applications of Biogas - Operation with I.C.Engine

UNIT-4

Ocean Energy - OTEC Principle - Lambert's law of absorption - Open cycle and closed cycle - heat exchanger calculations – Major problems and operational experience. Tidal Power - Principles of power generation - components of power plant – Single and two basin systems – Turbines for tidal power - Estimation of energy – Maximum and minimum power ranges - tidal powerhouse.Wave Energy – Concept of energy and power from waves – Wave characteristics – period and wave velocities - Different wave energy conservation devices (Saltor duck, oscillating water column and dolphin types) – operational experience.

UNIT-5

Geothermal Energy - Classification- Fundamentals of geophysics - Dry rock and hot aquifer energy analysis - Estimation of thermal power - Extraction techniques - Prime movers.

Course Outcomes:

After completion of this course the students will be able to:

- Identify alternate energy sources.
- Classify and analyze different renewable energy systems.
- Adopt different alternate energy sources for power generation.
- Adopt optimally usage of different sources and interconnection with grid.

Reference Books:

1. Renewable Energy Resources / John Twidell and Tony Weir / E &F.N.Spon
2. Renewable Energy Resources Basic Principles and Applications / G.N.Tiwari and M.K.Ghosal / Narosa
3. Solar Energy - Principles of thermal collection and storage/ S.P. Sukhatme / TMH
4. Solar Energy Thermal Processes,/Duffie& Beckman
5. Solar Heating and Cooling / Kreith&Kreider, CRC press.
6. Wind Energy Handbook / Tony Burton, David Sharpe, Nick Jenkins and Ervin Bossanyi / WileyWind Electrical Systems / S.N.Bhadra, D.Kastha and S.Banerjee / Oxford
7. Biogas Technology - A Practical Hand Book / K.Khendelwal& S.S. Mahdi / McGraw-Hill.

REACTIVE POWER COMPENSATION & MANAGEMENT
(Common to PE, P&ID, PE&ED, PE&D, PE&S, EM&D, HVE, PSHVE)

(Elective III)

Prerequisites: Brief idea of power system analysis, electric traction systems and Arc furnaces

Course Educational Objectives:

- To know the basic objectives of reactive power compensation.
- To know the types of compensation and their behaviour.
- To know the mathematical modeling of reactive power compensating devices.
- To know the reactive power compensation has to be done at distribution side.
- To know the role of reactive power compensation at electric traction systems and Arc furnaces.

UNIT-1:Load Compensation
Objectives and specifications – reactive power characteristics – inductive and capacitive approximate biasing – Load compensator as a voltage regulator – phase balancing and power factor correction of unsymmetrical loads- examples.

UNIT-2: Reactive power compensation in transmission system:
Steady state -Uncompensated line – types of compensation – Passive shunt and series and dynamic shunt compensation – examples
Transient state - Characteristic time periods – passive shunt compensation – static compensations- series capacitor compensation –compensation using synchronous condensers – examples

UNIT -3:Reactive power coordination:
Objective – Mathematical modeling – Operation planning – transmission benefits – Basic concepts of quality of power supply – disturbances- steady –state variations – effects of under voltages – frequency – Harmonics, radio frequency and electromagnetic interferences

UNIT -4:Distribution side Reactive power Management:
System losses –loss reduction methods – examples – Reactive power planning – objectives – Economics Planning capacitor placement – retrofitting of capacitor banks
User side reactive power management:
KVAR requirements for domestic appliances – Purpose of using capacitors – selection of capacitors – deciding factors – types of available capacitor, characteristics and Limitations

UNIT-5: Reactive power management in electric traction systems and are furnaces:
Typical layout of traction systems – reactive power control requirements – distribution transformers- Electric arc furnaces – basic operations- furnaces transformer –filter requirements – remedial measures –power factor of an arc furnace

Course Outcomes:

After completion of this course the students will be able to:

- Learn various load compensations.
- Obtain the mathematical model of reactive power compensating devices.
- Get application of reactive power compensation in electrical traction & arc furnaces.

Reference Books:

1. Reactive power control in Electric power systems by T.J.E.Miller, John Wiley and sons, 1982
2. Reactive power Management by D.M.Tagare,Tata McGraw Hill,2004

ELECTRICAL DISTRIBUTION SYSTEMS
(Common to PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

(Elective-III)

Prerequisites: Knowledge on basics of distribution systems, Compensation in electrical distribution systems, Circuit Analysis, concept of load modelling.

Course Educational Objectives:

- To learn the importance of economic distribution of electrical energy.
- To analyze the distribution networks for V-drops,P_{Loss}calculations and reactive power.
- To understand the co-ordination of protection devices.
- To impart knowledge of capacitive compensation/voltage control.
- To understand the principles of voltage control.

UNIT -1: (Residential, Commercial, Agricultural and Industrial) and their characteristics.

UNIT -2: Distribution Feeders and Substations : Design consideration of Distribution feeders: Radial and loop types of primary feeders, voltage levels, feeder-loading. Design practice of the secondary distribution system. Location of Substations : Rating of a Distribution Substation, service area with 'n' primary feeders. Benefits derived through optimal location of substations.

UNIT -3 : System analysis : Voltage drop and power loss calculations : Derivation for volt-drop and power loss in lines, manual methods of solution for radial networks, three-phase balanced primary lines, non-three-phase primary lines.

UNIT -4 : Protective devices and coordination : Objectives of distribution system protection, types of common faults and procedure for fault calculation. Protective Devices: Principle of operation of fuses, circuit reclosers, line sectionalizer and circuit breakers. Coordination of protective devices : General coordination procedure.

UNIT -5 : Capacitive compensation for power factor control: Different types of power capacitors, shunt and series capacitors, effect of shunt capacitors (Fixed and switched) power factor correction, capacitor location. Economic justification.Procedure to determine the best capacitor location. Voltage control: Equipment for voltage control, effect of series capacitors, effect of AVB/AVR, line drop compensation.

Course Outcomes:
After completion of this course the students will be able to:

- Analyze a distribution system.
- Design equipment for compensation of losses in the distribution system.
- Design protective systems and co-ordinate the devices.
- Understand of capacitive compensation.
- Understand of voltage control.

Reference Books:

1. "Electric Power Distribution System Engineering " byTuranGonen, Mc.Graw-Hill Book Company,1986.
2. Electric Power Distribution-by A.S.Pabla, Tata McGraw-Hill Publishing Company, 4th edition, 1997.
3. Electrical Distribution V.Kamaraju-McGraw Hill
4. .Handbook of Electrical Power Distribution – Gorti Ramamurthy-Universities press

I Year - II Semester	L	P	C
	4	0	3

SMART GRID TECHNOLOGIES
(Common to PS, PSC&A, PSE, PS&C, APS, EPE,
PE&ES, PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)
(Elective – IV)

Prerequisites: Basic knowledge on smart concept communication protocols, renewable energy systems and electronic circuits.

Course Educational Objectives:

- To understand concept of smart grid and developments on smart grid.
- To understand smart grid technologies and application of smart grid concept in hybrid electric vehicles etc.
- To have knowledge on smart substations, feeder automation and application for monitoring and protection.
- To have knowledge on micro grids and distributed energy systems.
- To know power quality aspects in smart grid.

UNIT 1

Introduction to Smart Grid: Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid, Concept of Resilient &Self Healing Grid, Present development & International policies on Smart Grid. Case study of Smart Grid.

UNIT 2

Smart Grid Technologies: Part 1: Introduction to Smart Meters, Real Time Prizing, Smart Appliances, Automatic Meter Reading(AMR), Outage Management System(OMS), Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation, Phase Shifting Transformers.

UNIT 3

Smart Grid Technologies: Part 2: Smart Substations, Substation Automation, Feeder Automation. Geographic Information System(GIS), Intelligent Electronic Devices(IED) & their application for monitoring & protection, Smart storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage, Wide Area Measurement System(WAMS), Phase Measurement Unit(PMU).

UNIT 4

Microgrids and Distributed Energy Resources: Concept of micro grid, need & applications of microgrid, formation of microgrid, Issues of interconnection, protection & control of microgrid. Plastic & Organic solar cells, Thin film solar cells, Variable speed wind generators, fuelcells, microturbines, Captive power plants, Integration of renewable energy sources.

UNIT 5

Power Quality Management in Smart Grid: Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.

Information and Communication Technology for Smart Grid: Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN).

Course Outcomes:

After completion of this course the students will be able to:

- Understand smart grids and analyse the smart grid policies and developments in smart grids.
- Develop concepts of smart grid technologies in hybrid electrical vehicles etc.
- Understand smart substations, feeder automation, GIS etc.
- Analyse micro grids and distributed generation systems.
- Analyse the effect of power quality in smart grid and to understand latest developments in ICT for smart grid.

Text Books:

1. Ali Keyhani, Mohammad N. Marwali, Min Dai "Integration of Green and Renewable Energy in Electric Power Systems", Wiley
2. Clark W. Gellings, "The Smart Grid: Enabling Energy Efficiency and Demand Response",CRC Press
3. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama,"Smart Grid: Technology and Applications", Wiley
4. Jean Claude Sabonnadière, NouredineHadjsaïd, "Smart Grids", Wiley Blackwell 19
5. Peter S. Fox Penner, "Smart Power: Climate Changes, the Smart Grid, and the Future of Electric Utilities", Island Press; 1 edition 8 Jun 2010
6. S. Chowdhury, S. P. Chowdhury, P. Crossley, "Microgrids and Active Distribution Networks." Institution of Engineering and Technology, 30 Jun 2009
7. Stuart Borlase, "Smart Grids (Power Engineering)", CRC Press

Reference Books:

1. Andres Carvallo, John Cooper, "The Advanced Smart Grid: Edge Power Driving Sustainability: 1", Artech House Publishers July 2011
2. James Northcote, Green, Robert G. Wilson "Control and Automation of Electric Power Distribution Systems (Power Engineering)", CRC Press
3. MladenKezunovic, Mark G. Adamiak, Alexander P. Apostolov, Jeffrey George Gilbert "Substation Automation (Power Electronics and Power Systems)", Springer
4. R. C. Dugan, Mark F. McGranghan, Surya Santoso, H. Wayne Beaty, "Electrical Power System Quality", 2nd Edition, McGraw Hill Publication
5. Yang Xiao, "Communication and Networking in Smart Grids", CRC Press

SPECIAL MACHINES
(Common to PE, P&ID, PE&ED, PE&D, PE&S, EM&D)
(Elective IV)

Prerequisites: Concepts of Electrical machines.

Course Educational Objectives:

- To know the concepts of special types of electrical machines.
- To understand the different control schemes for PMSM.
- To learn about the different sensor used in brushless DC motors.
- To draw the characteristics of servo motors, tacho meters and SRM.
- To understand the concepts of linear induction motor.

UNIT I: Stepper Motors

Constructional features, Principle of operation, Modes of excitation torque production in Variable Reluctance (VR) stepping motor, Dynamic characteristics, Drive systems and circuit for open loop control, closed loop control of stepping motor.

UNIT II: Permanent Magnet Synchronous Motors (PMSM) and Switched Reluctance Motors (SRM)

PMSM: Power electronic controllers, Torque speed characteristics, Self control, Vector control, Current control

SRM: Constructional features, Principle of operation. Torque equation, Characteristics, Control Techniques, Drive concept.

UNIT III: Permanent Magnet Brushless DC Motors

Concept of electronic commutation, Hall sensors, Optical sensors, back emf detection, Multiphase Brushless motor, Square wave permanent magnet brushless motor drives, Torque and emf equation, Torque-speed characteristics, Speed control by microcontroller.

UNIT IV: Servomotors and AC Tachometers

Servomotor – Types – Constructional features – Principle of Operation – Characteristics - Control – Microprocessor based applications.

AC Tachometers: Permanent magnet ac tachometer, AC induction tachometer, Schematic diagrams, Operating principle.

UNIT V: Linear Motors

Linear Motors: Linear Induction Motor (LIM) Classification – Construction – Principle of operation – Concept of Current sheet –Goodness factor – DC Linear Motor (DCLM) types – Circuit equation – DCLM control-applications.

Course Outcomes:

After completion of this course the students will be able to:

- Analyze the characteristics of different types of PM type brushless DC motors and design suitable controllers.
- Apply the knowledge of sensors used in PMSM which can be used for controllers and synchronous machines.
- Analyze the different controllers used in electrical machines to propose the suitability of drives for different industrial applications.
- Classify the types of DC linear motors and apply the knowledge of controllers to propose their application in real world.
- Evaluate the steady state and transient behavior linear induction motors.

References Books:

1. Miller, T.J.E. "Brushless Permanent Magnet and Reluctance Motor Drives", Clarendon Press, Oxford, 1989.
2. Kenjo, T, "Stepping Motors and their Microprocessor control", Clarendon Press, Oxford, 1989.
3. Naser A and Boldea I, "Linear Electric Motors: Theory, Design and Practical Application", Prentice Hall Inc., New Jersey,1987
4. Special Electrical Machines-K.Venkataratnam- University press
5. Floyd E Saner,"Servo Motor Applications", Pittman USA, 1993.
6. Kenjo, T and Naganori, S "Permanent Magnet and brushless DC motors", Clarendon Press, Oxford, 1989.
7. Generalized Theory of Electrical Machines – P.S.Bimbra-Khanna publications-5th edition-1995

PROGAMMABLE LOGIC CONTROLLERS & APPLICATIONS
(Common to PE, P&ID, PE&ED, PE&D, PE&S, EM&D, PE&PS)

(Elective IV)

Prerequisites: Knowledge on relay logic and digital electronics.

Course Educational Objectives:

- To have knowledge on PLC.
- To acquire the knowledge on programming of PLC.
- To understand different PLC registers and their description.
- To have knowledge on data handling functions of PLC.
- To know how to handle analog signal and converting of A/D in PLC.

UNIT 1:
PLC Basics: PLC system, I/O modules and interfacing, CPU processor, programming equipment, programming formats, construction of PLC ladder diagrams, devices connected to I/O modules.

UNIT 2:
PLC Programming: Input instructions, outputs, operational procedures, programming examples using contacts and coils. Drill press operation.Digital logic gates, programming in the Boolean algebra system, conversion examples. Ladder diagrams for process control: Ladder diagrams and sequence listings, ladder diagram construction and flow chart for spray process system.

UNIT 3:
PLC Registers: Characteristics of Registers, module addressing, holding registers, input registers, output registers. PLC Functions: Timer functions and Industrial applications, counters, counter function industrial applications, Arithmetic functions, Number comparison functions, number conversion functions.

UNIT 4:
Data Handling functions: SKIP, Master control Relay, Jump, Move, FIFO, FAL, ONS, CLR and Sweep functions and their applications. Bit Pattern and changing a bit shift register, sequence functions and applications, controlling of two axis and three axis Robots with PLC, Matrix functions.

UNIT 5:
Analog PLC operation: Analog modules and systems, Analog signal processing, multi bit data processing, analog output application examples, PID principles, position indicator with PID control, PID modules, PID tuning, PID functions.

Course Outcomes:

After completion of this course the students will be able to:

- Understand the PLCs and their I/O modules.
- Develop control algorithms to PLC using ladder logic etc.
- Manage PLC registers for effective utilization in different applications.
- Handle data functions and control of two axis and their axis robots with PLC.
- Design PID controller with PLC.

Reference Books:

1. Programmable Logic Controllers – Principle and Applications by John W. Webb and Ronald A. Reiss, Fifth Edition, PHI
2. Programmable Logic Controllers – Programming Method and Applications by JR. Hackworth and F.D Hackworth Jr. – Pearson, 2004.
3. Introduction to Programmable Logic Controllers- Gary Dunning-Cengage Learning.
4. Programmable Logic Controllers –W.Bolton-Elsevier publisher.

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I Year - II Semester

L	P	C
0	4	2

POWER CONVERTERS AND DRIVES LAB

Course Educational Objectives:

- To verify the operation of various converters and also their usage in the motor speed control application.

List of experiments

1. Analysis and speed control of DC motor drive using 3-phase full Converter.
2. Analysis of a four quadrant Chopper feeding DC motor.
3. Analysis of a 3-phase A.C. Voltage controller fed to R & RL - load.
4. Analysis of Buck, Boost, Buck-Boost DC-DC converters.
5. Analysis of Single Phase IGBT based PWM Inverter connected to R & R-L load
6. Analysis of 3-phase IGBT based PWM Inverterfeeding R & R-L load.
7. Analysis and speed control of 3 phase slip ring Induction motor by Static Rotor Resistance controller.
8. Analysis of three phase SVPWM Pulse generation using PIC Micro controller/DSP processor.
9. Analysis of DSP based V/F Control of 3 phase Induction motor.
10. Analysis of vector control based speed control of three phase Induction Motor drive.

Course Outcomes:

- To analyse the working of phase controlled converters, AC voltage controllers, DC-DC converters, and PWM inverters and analyse the speed control operation of power converter fed motors.

II Year - I Semester	**L**	**P**	**C**
	0	**0**	**2**

COMPREHENSIVE VIVA-VOCE

II Year - III Semester	L	P	C
	0	0	2

SEMINAR - I

II Year - III Semester	L	P	C
	0	0	16

PROJECT WORK PART - I

II Year - IV Semester

L	P	C
0	0	2

SEMINAR - II

	L	P	C
II Year - IV Semester	**0**	**0**	**18**

PROJECT WORK PART - II

ACADEMIC REGULATIONS &
COURSE STRUCTURE

For

POWER ELECTRONICS & POWER SYSTEMS (PE&PS)

(Applicable for batches admitted from 2016-2017)

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY: KAKINADA
KAKINADA - 533 003, Andhra Pradesh, India

I Semester

S. No.	Subject	L	P	Credits
1	Analysis of Power Electronic Converters	4	--	3
2	Digital Controllers	4	--	3
3	Reactive Power Compensation & Management	4	--	3
4	HVDC Transmission	4	--	3
5	**Elective – I** i. Renewable Energy Systems ii. Artificial Intelligence Techniques iii. Modern Control Theory	4	--	3
6	**Elective – II** i. Optimization Techniques ii. Power Quality iii. Power Semiconductor Devices & Protection	4	--	3
7	Simulation Laboratory	--	4	2
Total Credits				**20**

II Semester

S. No.	Subject	L	P	Credits
1	Switched Mode Power Conversion	4	--	3
2	Custom Power devices	4	--	3
3	Advanced Power System Protection	4	--	3
4	Flexible AC Transmission Systems	4	--	3
5	**Elective – III** i. Voltage Stability ii. Power System Deregulation iii. Power System Reliability	4	--	3
6	**Elective – IV** i. Smart Grid ii. Programmable Logic Controllers & Applications iii. Energy Auditing, Conservation and Management	4	--	3
7	Power Electronics & Power Systems Laboratory	--	4	2
Total Credits				**20**

III Semester

S. No.	Subject	L	P	Credits
1	Comprehensive Viva-Voce	**--**	**--**	2
2	Seminar – I	--	--	2
3	Project Work Part - I	--	--	16
Total Credits				**20**

IV Semester

S. No.	Subject	L	P	Credits
1	Seminar – II	--	--	2
2	Project Work Part - II	--	--	18
Total Credits				**20**

I Year - I Semester

L	P	C
4	0	3

ANALYSIS OF POWER ELECTRONIC CONVERTERS

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

Prerequisites: Knowledge on electrical circuit analysis, electronic devices and power electronics.

Course Educational Objectives:

- To understand the control principle of ac to ac conversion with suitable power semi-conductor devices.
- To have the knowledge of ac to dc conversion and different ac to dc converter topologies.
- To understand the effect of operation of controlled rectifiers on p.f. and improvement of p.f. with PFC converters
- To acquire the knowledge on dc-ac converters and to know the different control techniques of dc-ac converters.
- To know multilevel inverter configuration to improve the quality of the inverter output voltage.

UNIT-1 :AC voltage Controllers

Single Phase AC Voltage Controllers with RL and RLE loads-ac voltage controller's with PWM control-Effects of source and load inductances –synchronous tap changers –Application-numerical problems

Three Phase AC Voltage controllers-Analysis of Controllers with star and delta connected resistive, resistive –inductive loads-Effects of source and load inductances–Application-numerical problems.

UNIT –2: AC-DC converters

Single phase Half controlled and Fully controlled Converters with RL load– Evaluation of input power factor and harmonic factor-Continuous and Discontinuous load current-Power factor improvements-Extinction angle control-symmetrical angle control-PWM single phase sinusoidal PWM-Single phase series converters- numerical problems. Three Phase ac-dc Converters- Half controlled and fully controlled Converters with RL load– Evaluation of input power factor and harmonic factor-Continuous and Discontinuous load current-three phase dual converters-Power factor improvements-three phase PWM-twelve pulse converters- numerical problems

UNIT-3: Power Factor Correction Converters

Single-phase single stage boost power factor corrected rectifier, power circuit principle of operation, and steady state- analysis, three phase boost PFC converter

UNIT –4: PWM Inverters

Principle of operation-Voltage control of single phase inverters - sinusoidal PWM – modified PWM – phase displacement Control – Trapezoidal, staircase, stepped, harmonic injection and delta modulation – numerical problems. Voltage Control of Three-Phase Inverters- Sinusoidal PWM- 60^0 PWM- Third Harmonic PWM- Space Vector Modulation- Comparison of PWM Techniques-current source inverters-Variable dc link inverter - numerical problems

UNIT 5: Multi level inverters

Introduction, Multilevel Concept, Types of Multilevel Inverters- Diode-Clamped Multilevel Inverter, Principle of Operation, Features of Diode-Clamped Inverter, Improved Diode-Clamped Inverter- Flying-Capacitors Multilevel Inverter- Principle of Operation, Features of Flying-Capacitors Inverter- Cascaded Multilevel Inverter- Principle of Operation- Features of Cascaded Inverter- Switching Device Currents-DC-Link Capacitor Voltage Balancing- Features of Multilevel Inverters- Comparisons of Multilevel Converters

Course Outcomes:

After completion of this course the students will be able to:

- Have the knowledge on principle of ac voltage controller and their control techniques.
- Convert ac voltage to dc voltage and different control strategies of the converter.
- Control the power factor of single phase and three phase ac to dc converters.
- Understand the conversion of dc to ac and their control strategies.
- Analyze different multilevel inverters to improve the quality of the output voltage of the inverter.

Reference books:

1. Power Electronics-Md.H.Rashid –Pearson Education Third Edition- First Indian Reprint- 2008
2. Power Electronics- Ned Mohan, Tore M.Undelan and William P.Robbins –John Wiley & Sons -2nd Edition.
3. Power Electronics – Lander –Ed.2009
4. Modern power Electronics and AC Drives – B.K.Bose
5. Power Converter Circuits – William Shepherd & Li Zhang-Yes Dee Publishing Pvt Ltd.

I Year - I Semester

	L	P	C
	4	0	3

DIGITAL CONTROLLERS

Prerequisites: Basic concepts of switching theory & logic design and fundamentals of micro controllers.

Course Educational Objectives:

- To understand the architecture of PIC micro controller.
- To understand the architecture of DSP processor and their interface.
- To understand how to write the program for DSP processor using assembly Programming.
- To understand the different types of FPGA and configurations.
- To understand the basics of programming in Xilinx.

UNIT- I
PIC MICROCONTROLLERS
PIC Microcontrollers: Overview and Features, PIC 16C6X/7X, FSR(File Selection Register) [Indirect Data Memory Address Pointer], PIC Reset Actions, PIC Oscillator Connections, PIC Memory Organizations, PIC PIC 16C6X/7X Instructions, Addressing Modes, I/O Ports, Interrupts in PIC 16C61/71, PIC 16C61/71 Timers, PIC 16C71 Analog-to-Digital Converter (ADC)

UNIT - II
INTRODUCTION TO DSP
Introduction to the C2xx DSP core and code generation, The components of the C2xx DSP core, Mapping external devices to the C2xx core , peripherals and Peripheral Interface , System configuration registers , Memory , Types of Physical Memory , memory Addressing Modes , Assembly Programming using C2xx DSP, Instruction Set, Software Tools.

UNIT - III
I/O & CONTROL REGISTERS
Pin Multiplexing (MUX) and General Purpose I/O Overview, Multiplexing and General Purpose I/O Control Registers .Introduction to Interrupts, Interrupt Hierarchy, Interrupt Control Registers, Initializing and Servicing Interrupts in Software.

UNIT - IV
ADC & EVENT MANAGER
ADC Overview , Operation of the ADC in the DSP , Overview of the Event manager (EV) , Event Manager Interrupts , General Purpose (GP) Timers , Compare UNITs, Capture UNITs And Quadrature Enclosed Pulse (QEP) Circuitry , General Event Manager Information

UNIT - V
FPGA
Introduction to Field Programmable Gate Arrays – CPLD Vs FPGA – Types of FPGA , Xilinx XC3000 series , Configurable logic Blocks (CLB), Input/Output Block (IOB) – Programmable Interconnect Point (PIP) – Xilinx 4000 series – HDL programming – overview of Spartan 3E and Virtex II pro FPGA boards- case study.

Course Outcomes:
After completion of this course the students will be able to:

- Know the interfacing circuits for input and output to PIC micro controllers and DSP processors.
- Know how to write ALP for DSP processors.
- Design PWM controls for power electronic circuits using FPGA.

Reference Books:

1. Microcontrollers-Theory and Applications by Ajay V Deshmukh, McGraw Hills
2. Microcontrollers by Kennith J ayala, Thomson publishers
3. Microprocessor and Microcontrollers by Prof C.R.Sarma.
4. Hamid.A.Toliyat and Steven G.Campbell"DSP Based Electro Mechanical Motion Control " CRC Press New York , 2004.
5. XC 3000 series datasheets (version 3.1). Xilinx,Inc.,USA, 1998.
6. Wayne Wolf," FPGA based system design ", Prentice hall, 2004

I Year - I Semester	L	P	C
	4	0	3

REACTIVE POWER COMPENSATION & MANAGEMENT

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS)

Prerequisites: Brief idea of power system analysis, electric traction systems and Arc furnaces

Course Educational Objectives:

- To know the basic objectives of reactive power compensation.
- To know the types of compensation and their behavior.
- To know the mathematical modeling of reactive power compensating devices.
- To know the reactive power compensation has to be done at distribution side.
- To know the role of reactive power compensation at electric traction systems and Arc furnaces.

UNIT-1:Load Compensation

Objectives and specifications – reactive power characteristics – inductive and capacitive approximate biasing – Load compensator as a voltage regulator – phase balancing and power factor correction of unsymmetrical loads- examples.

UNIT-2: Reactive power compensation in transmission system:

Steady state -Uncompensated line – types of compensation – Passive shunt and series and dynamic shunt compensation – examples

Transient state - Characteristic time periods – passive shunt compensation – static compensations- series capacitor compensation –compensation using synchronous condensers – examples

UNIT -3:Reactive power coordination:

Objective – Mathematical modeling – Operation planning – transmission benefits – Basic concepts of quality of power supply – disturbances- steady –state variations – effects of under voltages – frequency – Harmonics, radio frequency and electromagnetic interferences

UNIT -4:Distribution side Reactive power Management:

System losses –loss reduction methods – examples – Reactive power planning – objectives – Economics Planning capacitor placement – retrofitting of capacitor banks

User side reactive power management:

KVAR requirements for domestic appliances – Purpose of using capacitors – selection of capacitors – deciding factors – types of available capacitor, characteristics and Limitations

UNIT-5: Reactive power management in electric traction systems and are furnaces:

Typical layout of traction systems – reactive power control requirements – distribution transformers- Electric arc furnaces – basic operations- furnaces transformer –filter requirements – remedial measures –power factor of an arc furnace

Course Outcomes:
After completion of this course the students will be able to:

- Learn various load compensations.
- Obtain the mathematical model of reactive power compensating devices.
- Get application of reactive power compensation in electrical traction & arc furnaces.

Reference Books:
1. Reactive power control in Electric power systems by T.J.E.Miller, John Wiley and sons, 1982
2. Reactive power Management by D.M.Tagare,Tata McGraw Hill,2004

I Year - I Semester	L	P	C
	4	0	3

HVDC TRANSMISSION

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D, HVE, PSHVE)

Prerequisites: Knowledge on Power Electronics, Power Systems and High Voltage Engineering

Course Educational Objectives:

- To learn various schemes of HVDC transmission.
- To learn about the basic HVDC transmission equipment.
- To learn the control of HVDC systems.
- To be exposed to the interaction between HVAC and HVDC system.
- To be exposed to the various protection schemes of HVDC engineering.

UNIT -1: Limitation of EHV AC Transmission, Advantages of HVDC Technical economical reliability aspects. HVDC Transmission: General considerations, Power Handling Capabilities of HVDC Lines, Basic Conversion principles, static converter configuration. Types of HVDC links-Apparatus and its purpose.

UNIT-2: Static Power Converters: 6-pulse bridge circuit and 12-pulse converters, converter station and Terminal equipment, commutation process, Rectifier and inverter operation, equivalent circuit for converter – special features of converter transformers. Comparison of the perform of diametrical connection with 6-pulse bridge circuit

UNIT-3 : Control of HVDC Converters and systems : constant current, constant extinction angle and constant Ignition angle control. Individual phase control and equidistant firing angle control, DC power flow control. Factors responsible for generation of Harmonics voltage and current harmonics effect of variation of α and μ. Filters Harmonic elimination.

UNIT-4 : Interaction between HV AC and DC systems – Voltage interaction, Harmonic instability problems and DC power modulation. Development of DC circuit Breakers, Multi-terminal DC links and systems; series, parallel and series parallel systems, their operation and control.

UNIT -5 : Transient over voltages in HV DC systems : Over voltages due to disturbances on DC side, over voltages due to DC and AC side line faults. Converter faults and protection in HVDC Systems: Converter faults, over current protection - valve group, and DC line protection, circuit breakers. Over voltage protection of converters, surge arresters.

Course Outcomes:

After completion of this course the students will be able to:

- Understand the various schemes of HVDC transmission.
- Understand the basic HVDC transmission equipment.
- Understand the control of HVDC systems.
- Understand the interaction between HVAC and HVDC system.
- Understand the various protection schemes of HVDC engineering.

Reference Books:

1. S Kamakshaih and V Kamaraju:HVDC Transmission- MG hill.
2. K.R.Padiyar : High Voltage Direct current Transmission, Wiley Eastern Ltd., New Delhi – 1992.
3. E.W. Kimbark : Direct current Transmission, Wiley Inter Science – New York.
4. J.Arillaga : H.V.D.C.Transmission Peter Peregrinus ltd., London UK 1983
5. Vijay K Sood :HVDC and FACTS controllers:Applications of static converters in power systems by, Kluwer Academic Press.

I Year - I Semester

L	P	C
4	0	3

RENEWABLE ENERGY SYSTEMS

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS)

(Elective-I)

Prerequisites: Basic idea of non-conventional energy sources.

Course Educational Objectives:

- To learn basic principle of renewable energy sources.
- To adoption of alternative energy sources for power generation.
- To learn alternative energy sources not based on sun.
- To the adoption and inter connection of renewable and alternative energy sources to grid.

UNIT-1

Solar Energy - Availability - Solar radiation data and measurement - Estimation of average solar radiation - Solar water heater types - Heat balance – Flat plate collector efficiency – Efficiency of heat removal - Thermo siphon flow calculation - Forced circulation calculation - Evacuated collectors - Basics of solar concentrators Solar Energy Applications - Solar air heaters – Solar Chimney - Crop driers - Passive solar system - Active solar systems - Water desalination - Output from solar still – Principle of solar ponds.

UNIT-2

Wind Energy – Nature of wind – Characteristics – Variation with height and time – Power in wind –Aerodynamics of Wind turbine – Momentum theory – Basics of aerodynamics – Aero foils and their characteristics – HAWT – Blade element theory – Prandtl's lifting line theory (prescribed wake analysis) VAWT aerodynamics – Wind turbine loads – Aerodynamic loads in steady operation – Yawed operation and tower shadow. Wind Energy Conversion System – Siting – Rotor selection – Annual energy output – Horizontal axis wind turbine (HAWT) – Vertical axis wind turbine (VAWT) – Rotor design considerations – Number of blades – Solidity - Blade profile – Upwind/Downwind – Yaw system – Tower – Braking system - Synchronous and asynchronous generators and loads – Integration of wind energy converters to electrical networks – Inverters – Control system – Requirement and strategies – Noise Applications of windenergy.

UNIT-3

Biomass energy - Bio fuel classification – Examples of thermo chemical, Pyrolysis, biochemical and agrochemical systems – Energy farming – Direct combustion for heat – Process heat and electricity – Ethanol production and use – Anaerobic digestion for biogas – Different digesters – Digester sizing – Applications of Biogas - Operation with I.C.Engine

UNIT-4

Ocean Energy - OTEC Principle - Lambert's law of absorption - Open cycle and closed cycle - heat exchanger calculations – Major problems and operational experience. Tidal Power - Principles of power generation - components of power plant – Single and two basin systems – Turbines for tidal power - Estimation of energy – Maximum and minimum power ranges - tidal powerhouse.Wave Energy – Concept of energy and power from waves – Wave characteristics – period and wave velocities - Different wave energy conservation devices (Saltor duck, oscillating water column and dolphin types) – operational experience.

UNIT-5

Geothermal Energy - Classification- Fundamentals of geophysics - Dry rock and hot aquifer energy analysis - Estimation of thermal power - Extraction techniques - Prime movers.

Course Outcomes:

After completion of this course the students will be able to:

- Identify alternate energy sources.
- Classify and analyze different renewable energy systems.
- Adopt different alternate energy sources for power generation.
- Adopt optimally usage of different sources and interconnection with grid.

Reference Books :

1. Renewable Energy Resources / John Twidell and Tony Weir / E &F.N.Spon
2. Renewable Energy Resources Basic Principles and Applications / G.N.Tiwari and M.K.Ghosal / Narosa
3. Solar Energy - Principles of thermal collection and storage/ S.P. Sukhatme / TMH
4. Solar Energy Thermal Processes,/Duffie& Beckman
5. Solar Heating and Cooling / Kreith&Kreider, CRC press.
6. Wind Energy Handbook / Tony Burton, David Sharpe, Nick Jenkins and Ervin Bossanyi / WileyWind Electrical Systems / S.N.Bhadra, D.Kastha and S.Banerjee / Oxford
7. Biogas Technology - A Practical Hand Book / K.Khendelwal& S.S. Mahdi / McGraw-Hill.

I Year - I Semester	L	P	C
	4	0	3

ARTIFICIAL INTELLIGENCETECHNIQUES

(Common to PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

(Elective I)

Prerequisites: Basic knowledge on human biological systems, concept of optimization and electrical engineering.

Course Educational Objectives:

- To have knowledge on concept of neural network.
- To know different types of neural networks and training algorithms.
- To understand the concept of genetic algorithm and its application in optimization.
- To have the knowledge on fuzzy logic and design of fuzzy logic controllers.
- To know the applications of AI Techniques in power electronics and DC drives.

UNIT – 1: Introduction to Neural Networks

Introduction, Humans and Computers, Biological Neural Networks, Historical development of neural network, Terminology and Topology, Biological and artificial neuron models, Basic learning laws.

UNIT- 2: Feed Forward Neural Networks

Introduction, Perceptron models: Discrete, continuous and multi-category, Training algorithms: Discrete and Continuous Perceptron Networks, Perceptron convergence theorem, Limitations and applications of the Perceptron model, Generalized delta learning rule, Feedforward recall and error back propagation training-Radial basis function algorithms-Hope field networks

UNIT -3: Genetic algorithms &Modelling-introduction-encoding-fitness function-reproduction operators-genetic operators-cross over and mutation-generational cycle-convergence of genetic algorithm

UNIT – 4: Classical and Fuzzy Sets

Introduction to classical sets - properties, operations and relations; Fuzzy sets, membership, Uncertainty, operations, properties, fuzzy relations, cardinalities, membership functions.
Fuzzy Logic System Components-Fuzzification, Membership value assignment, development of rule base and decision making system, defuzzification to crisp sets, defuzzification methods.

UNIT-5: Application of AI Techniques: Design of PI controller for speed control of DC motor using neural networks and fuzzy logic-PWM Controllers -Selected harmonic elimination PWM-Space vector PWM using neural network.

Course Outcomes: After completion of this course, students will be able to

- Understand neural networks and analyze different types of neural networks.
- Design training algorithms for neural networks.
- Develop algorithms using genetic algorithm for optimization.
- Analyze and designfuzzy logic systems.
- Apply AI Techniques in power electronics and DC drives.

Reference Books:

1. Neural Networks, Fuzzy logic, Genetic algorithms: synthesis and applications by Rajasekharan andPai – PHI Publication.
2. Introduction to Artificial Neural Systems - Jacek M. Zuarda, Jaico Publishing House, 1997.
3. Modern Power Electronics and AC Drives –B.K.Bose-Pearson Publications
4. Genetic Algorithms- David E Goldberg. Pearson publications.

MODERN CONTROL THEORY

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

(Elective-I)

Prerequisites: Control Systems, differential equations.

Course Educational Objectives:

- To facilitate the evolution of state variable approach for the analysis of control systems.
- To examine the importance of controllability and observability in modern control engineering.
- To enable students to analyze various types of nonlinearities & construction of trajectories using describing functions and phase plane analysis.
- To study the analysis of stability and instability of continuous time invariant system

UNIT –1: State Variable Analysis

The concept of state – State Equations for Dynamic systems – State diagram - Linear Continuous time model for physical systems – Existence and Uniqueness of Solutions to Continuous – Time State Equations – Solutions – Linear Time Invariant Continuous – Time State Equations – State transition matrix and it's properties

UNIT – 2: State Variable Techniques

General concept of Controllability - General concept of Observability Controllability tests for Continuous &Time Invariant systems - Observability tests for Continuous &Time Invariant systems - Controllability and Observability of state model in Jordan Canonical form - Controllability and Observability Canonical forms of State model – State feedback controller design through pole assignment.

UNIT – 3: Non Linear Systems – I

Introduction – Non Linear Systems – Types of Non – Linearities – Saturation – Dead – Zone – Backlash – Jump Phenomenon etc; - Singular Points – Introduction to Linearization of nonlinear systems, properties of Non Linear Systems – Describing function – describing function analysis of nonlinear systems- Stability analysis of Non – Linear systems through describing functions.

UNIT – 4: Non Linear Systems – II

Introduction to phase – plane analysis, Method of Isoclines for Constructing Trajectories, singular points, phase – plane analysis of nonlinear control systems.

UNIT – 5: Stability Analysis

Stability in the sense of Lyapunov, Lyapunov's stability and Lyapunov's instability theorems – Stability Analysis of the Linear Continuous time invariant systems by Lyapunov second method – Generation of Lyapunov functions – Variable gradient method – Krasooviski's method.

Course Outcomes:

After completion of this course the students will be able to:

- Understanding the state variable approach is suitable for higher order.
- To analyze the concepts of controllability and observability.
- To analyze the various non-linearities through describing functions and phase plane analysis.
- Typical issues of stability and instability of continuous time invariant systems.

Reference Books :

1. Modern Control System Theory by M. Gopal – New Age International – 1984
2. Modern Control Engineering by Ogata. K – Prentice Hall – 1997
3. Nonlinear systems, Hassan K. Klalil, Prentice Hall, 1996
4. Modern control systems, Richard C. Dorf and Robert H. Bishop, 11th Edition, Pearson Edu, India, 2009

I Year - I Semester	L	P	C
	4	0	3

OPTIMIZATION TECHNIQUES

(Common to PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

(Elective II)

Prerequisites: Concepts of engineering mathematics and mathematical methods.

Course Educational Objectives:

- To define an objective function and constraint functions in terms of design variables, and then state the optimization problem.
- To state single variable and multi variable optimization problems, without and with constraints.
- To explain linear programming technique to an optimization problem, define slack and surplus variables, by using Simplex method.
- To study and explain nonlinear programming techniques, unconstrained or constrained, and define exterior and interior penalty functions for optimization problems.
- To introduce evolutionary programming techniques.
- To introduce basic principles of Genetic Algorithms and Partial Swarm Optimization methods.

UNIT – I:
Introduction and Classical Optimization Techniques:
Statement of an Optimization problem – design vector – design constraints – constraint surface – objective function – objective function surfaces – classification of Optimization problems.
Single variable Optimization – multi variable Optimization without constraints – necessary and sufficient conditions for minimum/maximum – multivariable Optimization with equality constraints.Solution by method of Lagrange multipliers – multivariable Optimization with inequality constraints – Kuhn – Tucker conditions.

UNIT – II:
Linear Programming
Standard form of a linear programming problem – geometry of linear programming problems – definitions and theorems – solution of a system of linear simultaneous equations – pivotal reduction of a general system of equations – motivation to the simplex method – simplex algorithm - Duality in Linear Programming – Dual Simplex method.

UNIT – III:
Nonlinear Programming:
Unconstrained cases - One – dimensional minimization methods: Classification, Fibonacci method and Quadratic interpolation method - Univariate method, Powell's method and steepest descent method.
Constrained cases - Characteristics of a constrained problem, Classification, Basic approach of Penalty Function method; Basic approaches of Interior and Exterior penalty function methods.Introduction to convex Programming Problem.

UNIT – IV:

Introduction to Evolutionary Methods:

Evolutionary programming methods - Introduction to Genetic Algorithms (GA)– Control parameters –Number of generation, population size, selection, reproduction, crossover and mutation – Operator selection criteria – Simple mapping of objective function to fitness function – constraints – Genetic algorithm steps – Stopping criteria –Simple examples.

UNIT – V:

Introduction to Swarm Intelligence Systems:

Swarm intelligence programming methods - Basic Partial Swarm Optimization – Method – Characteristic features of PSO procedure of the global version – Parameters of PSO (Simple PSO algorithm – Operators selection criteria – Fitness function constraints) – Comparison with other evolutionary techniques – Engineering applications of PSO.

Course Outcomes:

After completion of this course the students will be able to:

- State and formulate the optimization problem, without and with constraints, by using design variables from an engineering design problem.
- Apply classical optimization techniques to minimize or maximize a multi-variable objective function, without or with constraints, and arrive at an optimal solution.
- Formulate a mathematical model and apply linear programming technique by using Simplex method. Also extend the concept of dual Simplex method for optimal solutions.
- Apply gradient and non-gradient methods to nonlinear optimization problems and use interior or exterior penalty functions for the constraints to derive the optimal solutions.
- Able to apply Genetic algorithms for simple electrical problems.
- Able to solve practical problems using PSO.

Text Books

1. "Engineering optimization: Theory and practice"-by S. S.Rao, New Age International (P) Limited, 3rd edition, 1998.
2. Soft Computing with Matlab Programming by N.P.Padhy&S.P.Simson, Oxford University Press – 2015

Reference Books:

1. **"**Optimization methods in operations Research and Systems Analysis" by K.V.Mital and C.Mohan, New Age International (P) Limited, Publishers, 3rd edition, 1996.
2. Genetic Algorithms in search, optimization, and Machine Learning by David E.Goldberg,ISBN:978-81-7758-829-3, Pearsonby Dorling Kindersley (India) Pvt. Ltd.
3. "Operations Research: An Introduction" by H.A.Taha, PHI pvt. Ltd., 6th edition.
4. Linear Programming by G.Hadley.,Narosa Publishers.

POWER QUALITY

(Common to PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

(Elective II)

Prerequisites: Knowledge on electric circuit analysis, power systems and power electronics.

Course Educational Objectives:

- To understand significance of power quality and power quality parameters.
- To know types of transient over voltages and protection of transient voltages.
- To understand harmonics, their effects, harmonic indices and harmonic minimization techniques.
- To understand long duration voltage variation and flicker
- To know power quality aspects in distributed generation.

UNIT-1 Introduction

Overview of Power Quality - Concern about the Power Quality - General Classes of Power Quality Problems – Transients -Long-Duration Voltage Variations - Short-Duration Voltage Variations - Voltage Unbalance - Waveform Distortion - Voltage fluctuation - Power Frequency Variations - Power Quality Terms - Voltage Sags and Interruptions - Sources of Sags and Interruptions – Nonlinear loads.

UNIT-2 Transient Over Voltages

Source of Transient Over Voltages - Principles of Over Voltage Protection - Devices for Over Voltage Protection - Utility Capacitor Switching Transients - Utility Lightning Protection - Load Switching Transient Problems - Computer Tools for Transient Analysis

UNIT-3 Harmonic Distortion and solutions

Voltage vs. Current Distortion - Harmonics vs. Transients - Power System Quantities under Nonsinusoidal Conditions - Harmonic Indices – Sources of harmonics - Locating Sources of Harmonics – System Response Characteristics - Effects of Harmonic Distortion – Interharmonics - Harmonic Solutions Harmonic Distortion Evaluation - Devices for Controlling Harmonic Distortion - Harmonic Filter Design - Standards on Harmonics

UNIT- 4 Long Duration Voltage Variations

Principles of Regulating the Voltage - Device for Voltage Regulation - Utility Voltage Regulator Application - Capacitor for Voltage Regulation - End-user Capacitor Application - Regulating Utility Voltage with Distributed Resources – Flicker

UNIT-5 Distributed Generation and Power Quality

Resurgence of Distributed Generation - DG Technologies - Interface to the Utility System - Power Quality Issues - Operating Conflicts - DG on Low Voltage Distribution Networks - Interconnection standards - Wiring and Grounding - Typical Wiring and Grounding Problems - Solution to Wiring and grounding Problems

Course Outcomes:

After completion of this course the students will be able to:

- Have the knowledge on causes of power quality, power quality parameters.
- Understand sources of transient over voltages and providing protection to transient over voltages.
- Understand effects of harmonics, sources of harmonics and harmonic minimization.
- Analyze long duration voltage variations and regulation of voltage variations.
- Describe power quality aspects in distributed generation and develop solutions to wiring and grounding problems.

Reference Books :

1. Electrical Power Systems Quality, Dugan R C, McGranaghan M F, Santoso S, and Beaty H W, Second Edition, McGraw-Hill, 2002.
2. Power Quality Primer, Kennedy B W, First Edition, McGraw-Hill, 2000.
3. Understanding Power Quality Problems: Voltage Sags and Interruptions, Bollen M H J, First Edition, IEEE Press; 2000.
4. Power System Harmonics, Arrillaga J and Watson N R, Second Edition, John Wiley & Sons, 2003.
5. Electric Power Quality control Techniques, W. E. Kazibwe and M. H. Sendaula, Van Nostrad Reinhold, New York.
6. Power Quality c.shankaran, CRC Press, 2001
7. Harmonics and Power Systems –Franciso C.DE LA Rosa-CRC Press (Taylor & Francis)
8. Power Quality in Power systems and Electrical Machines-EwaldF.fuchs, MohammadA.S. Masoum-Elsevier

POWER SEMICONDUCTOR DEVICES & PROTECTION
(Elective- II)

Prerequisites: Concepts of power electronic devices and their characteristics.

Course Educational Objectives:

- To understand i-v characteristics of power semi-conductor devices.
- To understand switching characteristics of power semi-conductor devices.
- To understand protection & thermal management methods of power semi-conductor devices.

UNIT I: introduction to Power Devices: Introduction to power switching devices, classification of devices, controlled and un-controlled devices, i-v characteristics of ideal and real switching devices, Device structure and i-v characteristics, ratings & specifications, switching characteristics, reverse recovery, classification of various diodes: Schotky diode, line frequency diodes, fast recovery diodes,

UNIT-II: Power Transistors& MOSFET: Device structure and i-v characteristics, ratings & specifications, switching characteristics, ON to OFF and OFF to ON state transitions, ON/OFF transition loss analysis, driver circuit.
Device structure and i-v characteristics, ratings & specifications, switching characteristics, ON to OFF and OFF to ON state transitions, ON/OFF transition loss analysis, driver circuit.

UNIT-III: Power IGBT: Device structure and i-v characteristics, ratings & specifications, switching characteristics, ON to OFF and OFF to ON state transitions, ON/OFF transition loss analysis,. Comparison of all the above devices with reference to power handling capability, frequency of operation, driver circuit, .emerging power switching devices.

UNIT-IV: Protection and thermal management: Device protection against over voltage/currents, di/dt and dv/dt; safe operating area, design of snubbers for power devices. Conduction and transition losses computation, thermal model of the device, steady-state temperature rise, electrical equivalent circuit of thermal model, sizing of the heat sink.

UNIT-V: Design of Passive Components: Magnetic circuit, review of design of line frequency inductors and transformers, design of high frequency inductors and transformers.

Course Outcomes:
After completion of this course the students will be able to:

- Analyse i-v characteristics of power semi-conductor devices.
- Analyse switching characteristics of power semi-conductor devices.
- Design protection circuit of power semi-conductor devices.
- Develop their model and equivalent circuits of power semi-conductor devices.
- Design line frequency & high frequency inductors and transformers for power semi-conductor devices.

Reference book:

1. Power Electronics Circuits- B. W. Williams
2.Power Electronics Circuits, Devices and Applications – M. H. Rashid-PHI-
3. Power Electronics –Converters, Applications and Design – Mohan and Undeland-John Wiley & Sons
4.Power Electronics: L. Umanand

I Year - I Semester

L	P	C
0	4	2

SIMULATION LAB

Course Educational Objectives:

- To understand the operation of power electronic systems and their applications by the simulation.
- To understand the modeling of various aspects of Power System analysis and develop the MATLAB programming.

Any five experiments are to be conducted from each section.

List of Experiments:

Section A: Power Electronics

1. Simulation analysis of three phase full converter using R-L-E Load.
2. Simulation analysis of three phase AC Voltage controller using RL load.
3. Simulation analysis of Buck, Boost and Buck-Boost DC-DC converters.
4. Simulation analysis of three phase converter fed DC motor.
5. Development and Simulation of 3-phase PWM Inverter with sinusoidal pulse-width modulation.
6. Simulation analysis of Volts/Hz closed-loop speed control of an induction motor drive.
7. Simulation analysis of Open-loop Volts/Hz control of a synchronous motor drive.

Section B: Power Systems

1. Formation of Y- Bus by Direct-Inspection Method.
2. Load Flow Solution Using Gauss Siedel Method
3. Load Flow Solution Using Newton Raphson Method
4. Formation of Z-Bus by Z-bus building algorithm
5. Symmetrical Fault analysis using Z-bus
6. Unsymmetrical Fault analysis using Z-bus
7. Economic Load Dispatch with & without transmission losses

Course Outcomes:

- After the completion of the lab they will verify the theoretical concepts of various aspects of power electronic systems operation & Power System analysis.

I Year - II Semester	L	P	C
	4	0	3

SWITCHED MODE POWER CONVERSION

(Common to PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

Perquisites: Concepts of electrical circuit analysis and power electronics.

Course Educational Objectives:

- To understand the control operation of non-sinusoidal DC-DC converters.
- To understand the basic operation of resonant converters.
- To understand the control operation of isolated DC-DC converters.
- To understand the control schemes of DC-DC converters and designing of magnetic components.
- To understand the modeling and control design of switch mode conversion based on linearization.
- To understand how to analyse the switch mode converters using small-signal analysis.

UNIT-I: Non-isolated switch mode converters:
Control of DC-DC converters, Buck converters, Boost converters, Buck-Boost converter, CUK Converter, Converter realization with nonideal components.

UNIT-II: Resonant converters:
Basic resonant circuit concepts, series resonant circuits, parallel resonant circuits, zero current switching Quasi-resonant buck converter, zero current switching Quasi-resonant boost converter, zero voltage switching Quasi-resonant buck converter, zero voltage switching Quasi-resonant boost converter

UNIT-III: Isolated switch-mode converters:
Forwarded converter, fly back converter, Push-pull converter, half-bridge converter, full bridge converter

UNIT-IV: Control schemes of switching converters:
Voltage-mode control, Current-mode control, control scheme for resonant converters, proportional integral controller.
Magnetic design consideration: Transformers design, DC inductor and capacitor design.

UNIT-V: Modeling& Control design based on linearization:
Formulation of averaged models for buck and boost converters average circuits models, small – signal analysis and linearization.
Control design based on linearization: Transfer function of converters, control design, large signal issues in voltage-mode & current-mode control.

Course Outcomes:
After completion of this course the students will be able to:

- Analyse the control operation of non-isolated switch mode converters.
- Analyse the operation of resonant converters and soft switching.
- Analyse the operation of isolated switch mode converters.
- Analyse the control schemes for resonant converters and design of magnetic components.
- Analyse the design of non-isolated switch mode converters based on linearization.
- Analyse the switch mode converters with small signal analysis.

Reference Books:

1. Power Electronics – IssaBataresh, Jhonwilley publications,2004
2. Power switching converters-simonang, alejandro olive, CRC Press (Taylor &franicsgroup).
3. Elements of Power Electronics – Philip T. Krein, Oxford University press.
4. Power Electronics: converters Applications & Design – Mohan, Undeland, Robbins-Wiley publications

I Year - II Semester

	L	P	C
	4	0	3

CUSTOM POWER DEVICES

(Common to PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

Prerequisites: Concept of power electronics and concept of reactive power compensation.

Course Educational Objectives:

- To understand the various power quality issues and their effects on the distribution circuits.
- To understand principle of working of various custom power devices.
- To understand the other custom power devices and their applications to power system.

UNIT 1-Introduction

Custom Power and Custom Power Devices - power quality variations in distribution circuits – Voltage Sags, Swells, and Interruptions - System Faults – Over voltages and Under voltages - Voltage Flicker - Harmonic Distortion - Voltage Notching - Transient Disturbances - Characteristics of Voltage Sags.

UNIT 2-Overview of Custom Power Devices

Reactive Power and Harmonic Compensation Devices - Compensation Devices for Voltage Sags and Momentary Interruptions - Backup Energy Supply Devices - Battery UPS – Super Conducting Magnetic Energy Storage systems - Flywheel – Voltage Source Converter - Multi-level converters

UNIT 3-Reactive Power and Harmonic Compensation Devices

Var control devices - Static Var Compensator – Topologies - Direct Connected Static Var Compensation for Distribution Systems – Static Series Compensator - Static Shunt Compensator (DSTATCOM) - Interaction with Distribution Equipment and System - Installation Considerations.

UNIT 4- High-Speed Source Transfer Switches, Solid State Limiting, And Breaking Devices:

Source Transfer Switch - Static Source Transfer Switch (SSTS),- Hybrid source transfer switch – High-speed mechanical source transfer switch - Solid state current limiter - Solid state breaker

UNIT 5-Application of Custom Power Devices in Power Systems

P-Q theory – Control of P and Q – Dynamic Voltage Restorer (DVR) – Operation and control – Interline Power Flow Controller (IPFC) – Operation and control – Unified Power Quality Conditioner (UPQC) – Operation and control. Recent custom power devices.

Course Outcomes: After completion of this course the students will be able to:

- Analyse the effect of various power quality issues in distribution system and their mitigation principles.
- Describe the operation of custom power devices for reactive power & harmonic compensation.
- Analyse high speed transfer switches.
- Analyse the operation and control of custom power devices in power system applications.

Text Books

1. Guidebook on Custom Power Devices, Technical Report, Published by EPRI, Nov 2000
2. **Power Quality Enhancement Using Custom Power Devices – Power Electronics and Power Systems, Gerard Ledwich, ArindamGhosh, Kluwer Academic Publishers, 2002.**

Reference Books:

1. Power Quality, C. Shankaran, CRC Press, 2001
2. Instantaneous power theory and application to power conditioning, H. Akagiet.al., IEEE Press, 2007.
3. Custom Power Devices - An Introduction, ArindamGhosh and Gerard Ledwich, Springer, 2002
4. **A Review of Compensating Type Custom Power Devices for Power Quality Improvement, Yash Pal et.al., Joint International Conference on Power System Technology and IEEE Power India Conference, 2008. POWERCON 2008.**

I Year - II Semester	L	P	C
	4	0	3

ADVANCED POWER SYSTEM PROTECTION

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS, HVE, PSHVE)

Prerequisites: Concepts of Power Electronics, Electronic circuits, STLD and basics of Relays and protection.

Course Educational Objectives:

- To learn about classification and operation of static relays.
- To understand the basic principles and application of comparators.
- To learn about static version of different types of relays.
- To understand about numerical protection techniques.

UNIT 1 : Static Relays classification and Tools : Comparison of Static with Electromagnetic Relays, Basic classification, Level detectors and Amplitude and phase Comparators – Duality – Basic Tools – Schmitt Trigger Circuit, Multivibrators, Square wave Generation – Polarity detector – Zero crossing detector – Thyristor and UJT Triggering Circuits. Phase sequence Filters – Speed and reliability of static relays.

UNIT 2 : Amplitude and Phase Comparators (2 Input) : Generalized equations for Amplitude and Phase comparison – Derivation of different characteristics of relays – Rectifier Bridge circulating and opposed voltage type amplitude comparators – Averaging & phase splitting type amplitude comparators – Principle of sampling comparators.

Phase Comparison : Block Spike and phase Splitting Techniques – Transistor Integrating type, phase comparison, Rectifier Bridge Type Comparison – Vector product devices.

UNIT 3 : Static over current (OC) relays – Instantaneous, Definite time, Inverse time OC Relays, static distance relays, static directional relays, static differential relays, measurement of sequence impedances in distance relays, multi input comparators, elliptic & hyperbolic characteristics, switched distance schemes, Impedance characteristics during Faults and Power Swings,

UNIT 4 : PILOT Relaying schemes: Wire pilot protection: circulating current scheme – balanced voltage scheme – translay scheme – half wave comparison scheme - carrier current protection: phase comparison type – carrier aided distance protection – operational comparison of transfer trip and blocking schemes – optical fibre channels.

UNIT 5 : Microprocessor based relays andNumerical Protection: Introduction – over current relays – impedance relay – directional relay – reactance relay.
Numerical Protection: Introduction - numerical relay - numerical relaying algorithms - mann-morrison technique - Differential equation technique and discrete fourier transform technique - numerical over current protection - numerical distance protection.

Course Outcomes:

After completion of this course the students will be able to:

- Know the classifications and applications of static relays.
- Understand the application of comparators.
- Understand the static version of different types of relays.
- Understand the numerical protection techniques.

Reference Books :

1. Power System Protection with Static Relays – by TSM Rao, TMH.
2. Protective Relaying Vol-II Warrington, Springer.
3. Art & Science of Protective Relaying - C R Mason, Willey.
4. Power System Stability KimbarkVol-II, Willey.
5. Power system protection & switchgear by Badri Ram & D N viswakarma, TMH.
6. Electrical Power System Protection –C.Christopoulos and A.Wright- Springer
7. Protection & Switchgear –BhaveshBhalaja,R.PMaheshwari, NileshG.Chothani-Oxford publisher

I Year - II Semester

L	P	C
4	0	3

FLEXIBLE AC TRANSMISSION SYSTEMS

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS, HVE, PSHVE)

Prerequisites: Concepts onPower Electronics and Power Systems

Course Educational Objectives:

- To study the performance improvements of transmission system with FACTS.
- To study the effect of static shunt compensation.
- To study the effect of static series compensation.
- To study the effect of UPFC.

UNIT 1 : FACTS concepts, Transmission interconnections, power flow in an AC System, loading capability limits, Dynamic stability considerations, importance of controllable parameters, basic types of FACTS controllers, benefits from FACTS controllers.

UNIT 2 : Basic concept of voltage and current source converters, comparison of current source converters with voltage source converters.

Static shunt compensation : Objectives of shunt compensation, midpoint voltage regulation, voltage instability prevention, improvement of transient stability, Power oscillation damping, methods of controllable var generation, variable impedance type static var generators, switching converter type var generators, hybrid var generators.

UNIT 3 :SVC and STATCOM : The regulation and slope transfer function and dynamic performance, transient stability enhancement and power oscillation damping, operating point control and summary of compensation control.

UNIT 4 : Static series compensators : Concept of series capacitive compensation, improvement of transient stability, power oscillation damping, functional requirements. GTO thyristor controlled series capacitor (GSC), thyristor switched series capacitor (TSSC), and thyristor controlled series capacitor (TCSC), control schemes for GSC, TSSC and TCSC.

UNIT 5 : Unified Power Flow Controller: Basic operating principle, conventional transmission control capabilities, independent real and reactive power flow control, comparison of the UPFC to series compensators and phase angle regulators.

Course Outcomes:
After completion of the course, the student will be able to:

- Know the performance improvement of transmission system with FACTS.
- Get the knowledge of effect of static shunt and series compensation.
- Know the effect of UPFC.
- Determine an appropriate FACTS device for different types of applications.

Reference Books :

1. "Understanding FACTS Devices" N.G.Hingorani and L.Guygi, IEEE Press.
   Indian Edition is available:--Standard Publications
2. Sang.Y.Hand John.A.T, "Flexible AC Transmission systems" IEEE Press (2006).
3. HVDC & FACTS Controllers: applications of static converters in power systems- Vijay K.Sood- Springer publishers

I Year - II Semester

L	P	C
4	0	3

VOLTAGE STABILITY

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS)

(Elective III)

Prerequisites: Basic concepts of power system analysis and power factor correction.

Course Educational Objectives:

- To study the importance of voltage stability.
- To study the various load modelling in power system.
- To study the effect of reactive power compensation and voltage control.
- To study the modelling of voltage stability static indices.
- To study the voltage stability margin and its improvement.

UNIT 1 : Reactive Power flow and voltage stability in power systems: Physical relationship indicating dependency of voltage on reactive power flow - reactive power, transient stability; Q-V curve; definition of voltage stability, voltage collapse and voltage security. Voltage collapse phenomenon, Factors of voltage collapse, effects of voltage collapse, voltage collapse analysis.

UNIT 2 : Power system loads : Load characteristics that influence voltage stability such as – Discharge lighting, Induction motor, Air conditioning and heat pumps, Electronic power supplies, Over Head lines and cables.

UNIT 3 : Reactive Power compensation : Generation and absorption of reactive power – Reactive power compensators & voltage controllers : - shunt capacitors, synchronous phase modifier – static VAR system – on load tap changing transformer, booster transformers.

UNIT 4 : Voltage stability static indices : Development of voltage collapse index – power flow studies – singular value decomposition – minimum singular value of voltage collapse – condition number as voltage collapse index.

UNIT 5 :voltage stability margins & Improvement of voltage stability: Stability margins, voltage stability margin of un compensated and compensated power system . Dynamic voltage stability – voltage security , Methods of improving voltage stability and its practical aspects.

Course Outcomes:

After completion of this course the students will be able to:

- Know the importance of voltage stability.
- Determine the load modelling of power systems.
- Get the knowledge of reactive power compensation and voltage control.
- Determine the modelling of static voltage stability indices.
- Know the voltage stability margin and its improvement.

Reference Books :

1. Performance operation and control of EHV power transmission Systems A. chakrabarti, D.P.Kothari, A.K. Mukhopadhyay, A.H. Wheeler publishing, 1995.
2. Power system Voltage stability - C.W. Taylor , Mc. Graw Hill, 1994

POWER SYSTEM DEREGULATION

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS, HVE, PSHVE)

(Elective III)

Prerequisites: Knowledge on power systems

Course Educational Objectives:

- To provide in-depth understanding of operation of deregulated electricity market systems.
- To examine typical issues in electricity markets and how these are handled world –wide in various markets.
- To enable students to analyze various types of electricity market operational and control issues using new mathematical models.

UNIT 1

Need and conditions for deregulation. Introduction of Market structure, MarketArchitecture, Spot market, forward markets and settlements.ReviewofConceptsmarginal cost of generation, least-cost operation, incremental cost of generation. Power System Operation.

UNIT 2

Electricity sector structures and Ownership /management, the forms of Ownership and management.Different structure model like Monopoly model, Purchasing agency model, wholesale competition model, Retail competition model.

UNIT 3

Framework and methods for the analysis of Bilateral and pool markets, LMP based markets, auction models and price formation, price based unit commitment, country practices

UNIT 4

Transmission network and market power. Power wheeling transactions and marginal costing, transmission costing.Congestion management methods- market splitting, counter-trading; Effect of congestion on LMPs- country practices

UNIT 5

Ancillary Services and System Security in Deregulation. Classifications and definitions, AS management in various markets- country practices. Technical, economic, & regulatory issues involved in the deregulation of the power industry.

Corse Outcomes:

After completion of this course the students will be able to:

- Understand of operation of deregulated electricity market systems
- Typical issues in electricity markets
- To analyze various types of electricity market operational and control issues using new mathematical models.

Reference Books:

1. Power System Economics: Designing markets for electricity - S. Stoft, wiley.
2. Power generation, operation and control, -J. Wood and B. F. Wollenberg, Wiley.
3. Operation of restructured power systems - K. Bhattacharya, M.H.J. Bollen and J.E. Daalder, Springer.
4. Market operations in electric power systems - M. Shahidehpour, H. Yaminand Z. Li,Wiley.
5. Fundamentals of power system economics - S. Kirschen and G. Strbac, Wiley.
6. Optimization principles: Practical Applications to the Operation and Markets of the Electric Power Industry - N. S. Rau, IEEE Press series on Power Engineeirng.
7. Competition and Choice in Electricity - Sally Hunt and Graham Shuttleworth, Wiley.

POWER SYSTEM RELIABILITY

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS)

(Elective – III)

Prerequisites: Probability theory, power systems.

Course Educational Objectives:

- Will be able to get the basic understanding of network modelling and reliability.
- Markov chains.
- Reliability analysis of generation systems.
- Decomposition techniques.

Unit 1 : Basic probability theory – rules for combining probabilities of events – Bernoulli`s trials – probability density and distribution functions – binomial- distributions – expected value and standard deviation of binomial distribution.

Unit 2 : Network Modelling and Reliability Analysis of Series, Parallel, Series-Parallel networks – complex networks – decomposition method
Reliability functions F(t), F(t), R(t), h(t) and their relationship – exponential distributions – Expected value and standard deviation of exponentional distribution – Bath tub curve – reliability analysis of series parallel networks using exponential distribution – reliability measures MTTF, MTTR, MTBF

Unit 3 : Markov chains – concept of stochastic transitional probability Matrix, Evaluation of limiting state Probabilities – Markov processes one component repairable system – time dependent probability evaluation using Laplace transform approach – evaluation of limiting state probabililties using STPM – two component repairable models – Frequency and duration concept – Evaluation of frequency of encountering state, mean cycletime, for one, two component repairable models – evaluation of cumulative probability and cumulative frequency of encountering merged states

Unit 4 : Generation system reliability analysis – reliability model of a generation system – recursive relation for unit addition and removal – load modelling – merging of generation load model – evaluation of transition rates for merged state model – cumulative Probability, cumulative frequency of failure evaluation – LOLP, LOLE.

Unit 5 : Composite system reliability analysis decomposition method – distribution system reliability analysis – radial networks – weather effects on transmission lines – Evaluation of load and energy indices.

Course Outcomes:
After completion of this course the students will be able to:

- Understand reliability analysis applied to power systems.
- Understand Markov Chains and application to power systems.
- Perform stability analysis of generation systems.
- Understand decomposition techniques applied to power system.

Reference Books :

1. Reliability Evaluation of Engg. System – R.Billinton, R.N.Allan, Plenum Press, New York.
2. Reliability Evaluation of Power System – R.Billinton, R.N.Allam, Plenum Press, New York
3. An Introduction to Realiability and Maintainability Engineering. Sharies E Ebeling, TATA McGraw Hill – Edition

I Year - II Semester	L	P	C
	4	0	3

SMART GRID TECHNOLOGIES

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

(Elective – IV)

Prerequisites: Basic knowledge on smart concept communication protocols, renewable energy systems and electronic circuits.

Course Educational Objectives:

- To understand concept of smart grid and developments on smart grid.
- To understand smart grid technologies and application of smart grid concept in hybrid electric vehicles etc.
- To have knowledge on smart substations, feeder automation and application for monitoring and protection.
- To have knowledge on micro grids and distributed energy systems.
- To know power quality aspects in smart grid.

Unit 1

Introduction to Smart Grid: Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid, Concept of Resilient &Self Healing Grid, Present development & International policies on Smart Grid. Case study of Smart Grid.

Unit 2

Smart Grid Technologies: Part 1: Introduction to Smart Meters, Real Time Prizing, Smart Appliances, Automatic Meter Reading(AMR), Outage Management System(OMS), Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation, Phase Shifting Transformers.

Unit 3

Smart Grid Technologies: Part 2: Smart Substations, Substation Automation, Feeder Automation. Geographic Information System(GIS), Intelligent Electronic Devices(IED) & their application for monitoring & protection, Smart storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage, Wide Area Measurement System(WAMS), Phase Measurement Unit(PMU).

Unit 4

Microgrids and Distributed Energy Resources: Concept of micro grid, need & applications of microgrid, formation of microgrid, Issues of interconnection, protection & control of microgrid. Plastic & Organic solar cells, Thin film solar cells, Variable speed wind generators, fuelcells, microturbines, Captive power plants, Integration of renewable energy sources.

Unit 5

Power Quality Management in Smart Grid: Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.**Information and Communication Technology for Smart Grid:** Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN).

Course Outcomes:

After completion of this course the students will be able to:

- Understand smart grids and analyse the smart grid policies and developments in smart grids.
- Develop concepts of smart grid technologies in hybrid electrical vehicles etc.
- Understand smart substations, feeder automation, GIS etc.
- Analyse micro grids and distributed generation systems.
- Analyse the effect of power quality in smart grid and to understand latest developments in ICT for smart grid.

Text Books:

1. Ali Keyhani, Mohammad N. Marwali, Min Dai "Integration of Green and Renewable Energy in Electric Power Systems", Wiley
2. Clark W. Gellings, "The Smart Grid: Enabling Energy Efficiency and Demand Response",CRC Press
3. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama,"Smart Grid: Technology and Applications", Wiley
4. Jean Claude Sabonnadière, NouredineHadjsaïd, "Smart Grids", Wiley Blackwell 19
5. Peter S. Fox Penner, "Smart Power: Climate Changes, the Smart Grid, and the Future of Electric Utilities", Island Press; 1 edition 8 Jun 2010
6. S. Chowdhury, S. P. Chowdhury, P. Crossley, "Microgrids and Active Distribution Networks." Institution of Engineering and Technology, 30 Jun 2009
7. Stuart Borlase, "Smart Grids (Power Engineering)", CRC Press

Reference Books:

1. Andres Carvallo, John Cooper, "The Advanced Smart Grid: Edge Power Driving Sustainability: 1", Artech House Publishers July 2011
2. James Northcote, Green, Robert G. Wilson "Control and Automation of Electric Power Distribution Systems (Power Engineering)", CRC Press
3. MladenKezunovic, Mark G. Adamiak, Alexander P. Apostolov, Jeffrey George Gilbert "Substation Automation (Power Electronics and Power Systems)", Springer
4. R. C. Dugan, Mark F. McGranghan, Surya Santoso, H. Wayne Beaty, "Electrical Power System Quality", 2nd Edition, McGraw Hill Publication
5. Yang Xiao, "Communication and Networking in Smart Grids", CRC Press

PROGAMMABLE LOGIC CONTROLLERS & APPLICATIONS(Common to PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

(Elective IV)

Prerequisites: Knowledge on relay logic and digital electronics.

Course Educational Objectives:

- To have knowledge on PLC.
- To acquire the knowledge on programming of PLC.
- To understand different PLC registers and their description.
- To have knowledge on data handling functions of PLC.
- To know how to handle analog signal and converting of A/D in PLC.

Unit 1:

PLC Basics: PLC system, I/O modules and interfacing, CPU processor, programming equipment, programming formats, construction of PLC ladder diagrams, devices connected to I/O modules.

Unit 2:

PLC Programming: Input instructions, outputs, operational procedures, programming examples using contacts and coils. Drill press operation.Digital logic gates, programming in the Boolean algebra system, conversion examples. Ladder diagrams for process control: Ladder diagrams and sequence listings, ladder diagram construction and flow chart for spray process system.

Unit 3:

PLC Registers: Characteristics of Registers, module addressing, holding registers, input registers, output registers. PLC Functions: Timer functions and Industrial applications, counters, counter function industrial applications, Arithmetic functions, Number comparison functions, number conversion functions.

Unit 4:

Data Handling functions: SKIP, Master control Relay, Jump, Move, FIFO, FAL, ONS, CLR and Sweep functions and their applications. Bit Pattern and changing a bit shift register, sequence functions and applications, controlling of two axis and three axis Robots with PLC, Matrix functions.

Unit 5:

Analog PLC operation: Analog modules and systems, Analog signal processing, multi bit data processing, analog output application examples, PID principles, position indicator with PID control, PID modules, PID tuning, PID functions.

Course Outcomes:

After completion of this course the students will be able to:

- Understand the PLCs and their I/O modules.
- Develop control algorithms to PLC using ladder logic etc.
- Manage PLC registers for effective utilization in different applications.
- Handle data functions and control of two axis and their axis robots with PLC.
- Design PID controller with PLC.

Reference Books:

1. Programmable Logic Controllers – Principle and Applications by John W. Webb and Ronald A. Reiss, Fifth Edition, PHI
2. Programmable Logic Controllers – Programming Method and Applications by JR. Hackworth and F.D Hackworth Jr. – Pearson, 2004.
3. Introduction to Programmable Logic Controllers- Gary Dunning-Cengage Learning.
4. Programmable Logic Controllers –W.Bolton-Elsevier publisher

ENERGY AUDITING, CONSERVATION & MANAGEMENT
(Elective IV)

Perquisites : Concepts of utilization of electrical energy, electrical machines and electrical measurements.

Course Educational Objectives:

- To learn principle of energy audit as well as management for industries and utilities and buildings.
- To study the energy efficient motors and lighting.
- To learn power factor improvement methods and operation of different energy instruments.
- To compute depreciation methods of equipment for energy saving.

Unit I: Basic Principles of Energy Audit

Energy audit- definitions, concept , types of audit, energy index, cost index ,pie charts, Sankey diagrams, load profiles, Energy conservation schemes- Energy audit of industries- energy saving potential, energy audit of process industry, thermal power station, building energy audit

Unit II: Energy Management –I

Principles of energy management, organizing energy management program, initiating, planning, controlling, promoting, monitoring, reporting. Energy manger, Qualities and functions, language, Questionnaire – check list for top management

Unit III: Energy Efficient Motors and Lighting

Energy efficient motors , factors affecting efficiency, loss distribution , constructional details , characteristics – variable speed , variable duty cycle systems, RMS hp- voltage variation-voltage unbalance- over motoring- motor energy audit. Good lighting system design and practice, lighting control, lighting energy audit

Unit IV: Power Factor Improvement and energy instruments

Power factor – methods of improvement , location of capacitors , Power factor with non-linear loads, effect of harmonics on p.f. , p.f motor controllers – Energy Instruments- watt meter, data loggers, thermocouples, pyrometers, lux meters, tongue testers ,application of PLC's

Unit V: Economic Aspects and their computation

Economics Analysis-Depreciation Methods, time value of money, rate of return, present worth method, replacement analysis, lifecycle costing analysis – Energy efficient motors. Calculation of simple payback method, net present worth method- Power factor correction, lighting – Applications of life cycle costing analysis, return on investment.

Course Outcomes: After completion of this course the students will be able to:

- Perform energy audit in different organizations.
- Recommend energy efficient motors and design good lighting system.
- Understand advantages to improve the power factor.
- Evaluate the depreciation of equipment.

Reference Books:

1. Energy management by W.R. Murphy & G. Mckay Butter worth, Heinemann publications.
2. Energy efficient electric motors by John .C. Andreas, Marcel Dekker Inc Ltd-2nd edition, 1995-
3. Energy management by Paul o' Callaghan, Mc-graw Hill Book company-1st edition, 1998
4. Energy management hand book by W.C.Turner, John wiley and sons
5. Energy management and good lighting practice : fuel efficiency- booklet12-EEO

I Year - II Semester	L	P	C
	4	0	3

POWER SYSTEMS LABORATORY

Course Educational Objectives:

- To verify the operation of various converters and also their usage in the motor speed control application.
- To understand the experimental determination of various parameters used in power system area and to study the performance of transmission with & without compensation.

Any five experiments are to be conducted from each section.

List of Experiments:

Section A: Power Electronics

1. Operation of 3- phases Full-Converter on R & R-L load.
2. Performance & speed control of D.C. drive using 3-phase full Converter.
3. Performance & Operation of a four quadrant Chopper on D.C. Drive
4. Performance & Operation of a 3-phase A.C. Voltage controller on RL load.
5. Operation of 3-phase IGBT based PWM Inverter on R & R-L load.
6. Three phase PWM Pulse generation using PIC Micro controller
7. DSP based V/F Control of 3 phase Induction motor.

Section B: Power Systems

1. Determination of Sequence Impendence of an Alternator by Direct method.
2. Determination of Sequence impedance of an Alternator by fault Analysis.
3. Measurement of sequence impedance of a three phase transformer
   (a)by application of sequence voltage.
   (b)using fault analysis.
4. Power angle characteristics of a salient pole Synchronous Machine.
5. Poly-phase connection on three single phase transformers and measurement of phase displacement.
6. Determination of equivalent circuit of 3-winding Transformer.
7. Measurement of ABCD parameters on transmission line model.

Course Outcomes:

- To analyse the working of phase controlled converters, AC voltage controllers, DC-DC converters and PWM inverters and analyse the speed control operation of power converter fed motors.
- To understand the procedure for determination of various parameters used in power system and performance of transmission lines.

	L	P	C
II Year - III Semester	**0**	**0**	**2**

COMPREHENSIVE VIVA-VOCE

II Year - III Semester	L	P	C
	0	0	2

SEMINAR - I

II Year - III Semester	L	P	C
	0	0	16

PROJECT WORK PART - I

II Year - IV Semester	L	P	C
	0	0	2

SEMINAR - II

	L	P	C
II Year - IV Semester	**0**	**0**	**18**

PROJECT WORK PART – II

ACADEMIC REGULATIONS &
COURSE STRUCTURE

For

POWER SYSTEMS (PS)
POWER SYSTEM CONTROL AND AUTOMATION (PSC&A)
POWER SYSTEM ENGINEERING (PSE)
POWER SYSTEM CONTROL (PSC)
ADVANCED POWER SYSTEMS (APS)
ELECTRICAL POWER ENGINEERING (EPE)
POWER ENGINEERING & ENERGY SYSTEMS (PE&ES)
(Applicable for batches admitted from 2016-2017)

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY: KAKINADA
KAKINADA - 533 003, Andhra Pradesh, India

I Semester

S. No.	Subject	L	P	Credits
1	Microprocessors & Microcontrollers	4	--	3
2	HVDC Transmission	4	--	3
3	Power System Operation and Control	4	--	3
4	Reactive Power Compensation & Management	4	--	3
5	**Elective – I** i. Electrical Distribution Systems ii. EHVAC Transmission iii. Analysis of Power Electronics Converters iv. Renewable Energy Systems v. Artificial Intelligence Techniques	4	--	3
6	**Elective – II** i. Power System Security ii Advanced Digital Signal Processing iii. Generation & Measurement of High Voltages iv. Programmable Logic Controllers & Applications v. Modern Control Theory	4	--	3
7	Simulation Laboratory	--	4	2
Total Credits				**20**

II Semester

S. No.	Subject	L	P	Credits
1	Power System Dynamics and Stability	4	--	3
2	Flexible AC Transmission Systems	4	--	3
3	Real Time Control of Power Systems	4	--	3
4	Advanced Power System Protection	4	--	3
5	**Elective – III** i. Smart Grid Technologies ii. Power Quality iii. Power System Reliability iv. Voltage Stability	4	--	3
6	**Elective – IV** i. Power System Deregulation ii.High Voltage Testing Techniques iii.Power System Transients iv.Demand Side Energy Management	4	--	3
7	Power Systems Laboratory	--	4	2
Total Credits				**20**

III Semester

S. No.	Subject	L	P	Credits
1	Comprehensive Viva-Voce	**--**	**--**	2
2	Seminar – I	--	--	2
3	Project Work Part - I	--	--	16
Total Credits				**20**

IV Semester

S. No.	Subject	L	P	Credits
1	Seminar – II	--	--	2
2	Project Work Part - II	--	--	18
Total Credits				**20**

I Year - I Semester

L	P	C
4	0	3

MICROPROCESSORS &MICRO CONTROLLERS

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES)

Prerequisites: Basic Knowledge of digital electronics, analog electronics and computers.

Course Educational Objectives:

- To learn the basic architecture of 8086.
- To learn the assembly language programming using 8086.
- To teach various peripheral devices to interface processor with different components.
- Tolearn the 8051 micro controller and its various modes of operation and its instruction set.

Unit-1: Register Organization of 8086, Architecture, Signal description of 8086, memory segmentation, addressing modes of 8086. 8086/8088 instruction set and assembler directives, machine language instruction formats, Assembly language Programs.

Unit-2: General Bus Operation, minimum mode operation of 8086 and timing diagrams, Fundamental I/O considerations, Programmed I/O, Interrupt I/O, Block transfers and DMA.

Unit-3: Introduction to stack, stack structure of 8086/8088, Interrupts and Interrupt service routine, interrupt cycle of 8086/8088. Interfacing ROM/RAM, Interfacing of I/O ports to Micro Computer System, PPI (Programmable Peripheral Interface), 8255 modes of operation, Interfacing A to D converters, Interfacing D to A converters, Interfacing Principles and stepper motor interfacing.

Unit-4: Programmable Interval timer 8254, Programmable Interrupt Controller 8259A, Key Board or Display Controller 8279, Programmable Communication Interface 8251 USART.

Unit-5: Introduction to 8051/31 Micro Controller, PIN diagram, architecture, Different modes of Operation of timer/counters, addressing modes of 8051 and instruction set. Over view of 16 bit Microcontrollers.

Course Outcomes:

Aftercompletion ofthis coursethe students will be able to:

- Understand the basic architecture of 8086.
- Develop assembly language programming using 8086.
- Understand various peripheral devices to interface processor with different components.
- Understand the 8051 micro controller and its various modes of operation and its instruction set.

Reference Books:

1. Microprocessors and Interfacing: Programming and Hardware by DouglasV. Hall, 2nd edition, TMH, New Delhi, 1999.
2. Advanced Microprocessors and Peripherals, Architecture Programming and Interfacing by A.K. Ray & K.M. Bhurchandi, Forth reprint 2004, TMH
3. The 8051Microcontrollers: Architecture, Programming & Applications by Kenneth J Ayala, Second Edition, Penram International Publishing (India).
4. Micro Computer Systems: The 8086/8088 family by YU-CHENG LIU, GLENN A.GIBSON, 2nd edition, PHI India, 2000.
5. The 8051 Microcontroller and Embedded Systems – Mohammad Ali Mazdi, Janice GillispieMazidi, Pearson Education (Singapore) Pvt. Ltd., 2003.

I Year - I Semester	L	P	C
	4	0	3

HVDC TRANSMISSION

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE, PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

Prerequisites: Knowledge onPower Electronics, Power Systems and High Voltage Engineering

Course Educational Objectives:

- To learn various schemes of HVDC transmission.
- To learn about the basic HVDC transmission equipment.
- To learn the control of HVDC systems.
- To be exposed to the interaction between HVAC and HVDC system.
- To be exposed to the various protection schemes of HVDC engineering.

Unit -1: Limitation of EHV AC Transmission, Advantages of HVDC Technical economical reliability aspects. HVDC Transmission: General considerations, Power Handling Capabilities of HVDC Lines, Basic Conversion principles, static converter configuration. Types of HVDC links- Apparatus and its purpose.

Unit-2: Static Power Converters: 6-pulse bridge circuit and 12-pulse converters, converter station and Terminal equipment, commutation process, Rectifier and inverter operation, equivalent circuit for converter – special features of converter transformers. Comparison of the perform of diametrical connection with 6-pulse bridge circuit

Unit-3 : Control of HVDC Converters and systems : constant current, constant extinction angle and constant Ignition angle control. Individual phase control and equidistant firing angle control, DC power flow control. Factors responsible for generation of Harmonics voltage and current harmonics effect of variation of α and μ. Filters Harmonic elimination.

Unit-4 : Interaction between HV AC and DC systems – Voltage interaction, Harmonic instability problems and DC power modulation. Development of DC circuit Breakers, Multi-terminal DC links and systems; series, parallel and series parallel systems, their operation and control.

Unit -5 : Transient over voltages in HV DC systems : Over voltages due to disturbances on DC side, over voltages due to DC and AC side line faults. Converter faults and protection in HVDC Systems: Converter faults, over current protection - valve group, and DC line protection, circuit breakers. Over voltage protection of converters, surge arresters.

Course Outcomes:

Aftercompletion ofthis coursethe students will be able to:

- Understand the various schemes of HVDC transmission.
- Understand the basic HVDC transmission equipment.
- Understand the control of HVDC systems.
- Understand the interaction between HVAC and HVDC system.
- Understand the various protection schemes of HVDC engineering.

Reference Books:

1. S Kamakshaih and V Kamaraju:HVDC Transmission- MG hill.
2. K.R.Padiyar : High Voltage Direct current Transmission, Wiley Eastern Ltd., New Delhi – 1992.
3. E.W. Kimbark : Direct current Transmission, Wiley Inter Science – New York.
4. J.Arillaga : H.V.D.C.Transmission Peter Peregrinus ltd., London UK 1983
5. Vijay K Sood :HVDC and FACTS controllers:Applications of static converters in power systems by, Kluwer Academic Press.

I Year - I Semester	L	P	C
	4	0	3

POWER SYSTEM OPERATION AND CONTROL

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE)

Prerequisites: Knowledge on Power Generation Engineering, Power Transmission Engineering.

Course Educational Objectives:

- To study the unit commitment problem for economic load dispatch.
- To study the load frequency control of single area and two area systems with and without control.
- To study the effect of generation with limited energy supply.
- To study the effectiveness of interchange evaluation in interconnected power systems.

Unit-1 : Unit commitment problem and optimal power flow solution : Unit commitment : Constraints in UCP,UC solutions. Methods-priority list method, introduction to Dynamic programming Approach.

Unit-2 : Single area Load Frequency Control: Necessity of keeping frequency constant. Definition of control area, single area control, Block diagram representation of an isolated Power System, Steady State analysis, Dynamic response-Uncontrolled case. Proportional plus Integral control of single area and its block diagram representation, steady state response, load frequency control and Economic dispatch control.

Unit-3 : Two area Load Frequency Control : Load frequency control of 2-area system : uncontrolled case and controlled case, tie-line bias control. Optimal two-area LF control-steady state representation, performance Index and optimal parameter adjustment.

Unit-4 : Generation with limited Energy supply : Take-or-pay fuel supply contract, composite generation production cost function. Solution by gradient search techniques, Hard limits and slack variables, Fuel scheduling by linear programming.

Unit-5 : Interchange Evaluation and Power Pools Economy Interchange, Economy interchange Evaluation, Interchange Evaluation with unit commitment, Multiple Interchange contracts. After-the-fact production costing, Transmission Losses in transaction Evaluation, other types of Interchange, power pools.

Course Outcomes:

Aftercompletion ofthis course the students will be able to:

- Determine the unit commitment problem for economic load dispatch.
- Get the knowledge of load frequency control of single area and two area systems with and without control.
- Know the effect of generation with limited energy supply.
- Determine the interchange evaluation in interconnected power systems.

Reference Books :

1 Modern Power System Analysis - by I.J.Nagrath&D.P.Kothari, Tata McGraw-Hill Publishing Company ltd, 2^{nd} edition.

2 Power system operation and control PSR Murthy B.S publication.

3 Power Generation, Operation and Control - by A.J.Wood and B.F.Wollenberg,Johnwiley& sons Inc. 1984.

4 Electrical Energy Systems Theory - by O.I.Elgerd, Tata McGraw-Hill Publishing Company Ltd, 2^{nd} edition.

5 Reactive Power Control in Electric Systems - by TJE Miller, John Wiley & sons.

I Year - I Semester	L	P	C
	4	0	3

REACTIVE POWER COMPENSATION & MANAGEMENT

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS)

Prerequisites: Brief idea of power system analysis, electric traction systems and Arc furnaces

Course Educational Objectives:

- To know the basic objectives of reactive power compensation.
- To know the types of compensation and their behavior.
- To know the mathematical modeling of reactive power compensating devices.
- To know the reactive power compensation has to be done at distribution side.
- To know the role of reactive power compensation at electric traction systems and Arc furnaces.

Unit-1:Load Compensation

Objectives and specifications – reactive power characteristics – inductive and capacitive approximate biasing – Load compensator as a voltage regulator – phase balancing and power factor correction of unsymmetrical loads- examples.

Unit-2: Reactive power compensation in transmission system:

Steady state -Uncompensated line – types of compensation – Passive shunt and series and dynamic shunt compensation – examples

Transient state - Characteristic time periods – passive shunt compensation – static compensations- series capacitor compensation –compensation using synchronous condensers – examples

Unit -3:Reactive power coordination:

Objective – Mathematical modeling – Operation planning – transmission benefits – Basic concepts of quality of power supply – disturbances- steady –state variations – effects of under voltages – frequency – Harmonics, radio frequency and electromagnetic interferences

Unit -4:Distribution side Reactive power Management:

System losses –loss reduction methods – examples – Reactive power planning – objectives – Economics Planning capacitor placement – retrofitting of capacitor banks

User side reactive power management:

KVAR requirements for domestic appliances – Purpose of using capacitors – selection of capacitors – deciding factors – types of available capacitor, characteristics and Limitations

Unit-5: Reactive power management in electric traction systems and are furnaces:

Typical layout of traction systems – reactive power control requirements – distribution transformers- Electric arc furnaces – basic operations- furnaces transformer –filter requirements – remedial measures –power factor of an arc furnace

Course Outcomes:

After completion of this course the students will be able to:

- Learn various load compensations.
- Obtain the mathematical model of reactive power compensating devices.
- Get application of reactive power compensation in electrical traction & arc furnaces.

Reference Books:

1. Reactive power control in Electric power systems by T.J.E.Miller, John Wiley and sons, 1982
2. Reactive power Management by D.M.Tagare,Tata McGraw Hill,2004

I Year - I Semester	L	P	C
	4	0	3

ELECTRICAL DISTRIBUTION SYSTEMS

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES)

(ELECTIVE-I)

Prerequisites: Knowledge on basics of distribution systems, Compensation in electrical distribution systems, Circuit Analysis, concept of load modelling.

Course Educational Objectives:

- To learn the importance of economic distribution of electrical energy.
- To analyze the distribution networks for V-drops,P_{Loss}calculations and reactive power.
- To understand the co-ordination of protection devices.
- To impart knowledge of capacitive compensation/voltage control.
- To understand the principles of voltage control.

Unit -1: (Residential, Commercial, Agricultural and Industrial) and their characteristics.

Unit -2: Distribution Feeders and Substations : Design consideration of Distribution feeders: Radial and loop types of primary feeders, voltage levels, feeder-loading. Design practice of the secondary distribution system. Location of Substations : Rating of a Distribution Substation, service area with 'n' primary feeders. Benefits derived through optimal location of substations.

Unit -3 : System analysis : Voltage drop and power loss calculations : Derivation for volt-drop and power loss in lines, manual methods of solution for radial networks, three-phase balanced primary lines, non-three-phase primary lines.

Unit -4 : Protective devices and coordination : Objectives of distribution system protection, types of common faults and procedure for fault calculation. Protective Devices: Principle of operation of fuses, circuit reclosers, line sectionalizer and circuit breakers. Coordination of protective devices : General coordination procedure.

Unit -5 : Capacitive compensation for power factor control: Different types of power capacitors, shunt and series capacitors, effect of shunt capacitors (Fixed and switched) power factor correction, capacitor location. Economic justification.Procedure to determine the best capacitor location. Voltage control : Equipment for voltage control, effect of series capacitors, effect of AVB/AVR, line drop compensation.

Course Outcomes:

After completion of this course the students will be able to:

- Analyze a distribution system.
- Design equipment for compensation of losses in the distribution system.
- Design protective systems and co-ordinate the devices.
- Get understanding of capacitive compensation.
- Get understanding of voltage control.

Reference Books:

1. “Electric Power Distribution System Engineering “ byTuranGonen, Mc.Graw-Hill Book Company,1986.
2. Electric Power Distribution-by A.S.Pabla, Tata McGraw-Hill Publishing Company, 4th edition, 1997.
3. Electrical Distribution V.Kamaraju-McGraw Hill
4. .Handbook of Electrical Power Distribution – Gorti Ramamurthy-Universities press

EHVAC TRANSMISSION

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES)

(ELECTIVE-I)

Prerequisites: Transmission line parameters and properties, Corona etc.

Course Educational Objectives:

- To calculate the transmission line parameters.
- To calculate the field effects on EHV and UHV AC lines.
- To have knowledge of corona, RI and audible noise in EHV and UHV lines.
- To have knowledge of voltage control and compensation problems in EHV and UHV transmission systems.

Unit-1:E.H.V. A.C. Transmission , line trends and preliminary aspects ,standard transmission voltages – power handling capacities and line losses – mechanical aspects. Calculation of line resistance and inductance: resistance of conductors, temperature rise of conductor and current carrying capacity. Properties of bundled conductors and geometric mean radius of bundle, inductance of two conductor lines and multi conductor lines, Maxwell's coefficient matrix. Line capacitance calculation.capacitance of two conductor line, and capacitance of multi conductor lines, potential coefficients for bundled conductor lines, sequence inductances and capacitances and diagonalization.

Unit-2 : Calculation of electro static field of AC lines - Effect of high electrostatic field on biological organisms and human beings. Surface voltage Gradient on conductors, surface gradient on two conductor bundle and cosine law, maximum surface voltage gradient of bundle with more than 3 sub conductors, Mangolt formula.

Unit-3 : Corona : Corona in EHV lines – corona loss formulae – attenuation of traveling waves due to corona – Audio noise due to corona, its generation, characteristics and limits, measurement of audio noise.

Unit-4 : Power Frequency voltage control : Problems at power frequency, generalized constants, No load voltage conditions and charging currents, voltage control using synchronous condenser, cascade connection of components : Shunt and series compensation, sub synchronous resonance in series – capacitor compensated lines

Unit -5 : Static reactive compensating systems : Introduction, SVC schemes, Harmonics injected into network by TCR, design of filters for suppressing harmonics injected into the system.

Course Outcomes:

After completion of this course the students will be able to:

- Calculate the transmission line parameters.
- Calculate the field effects on EHV and UHV AC lines.
- Determine the corona, RI and audible noise in EHV and UHV lines.
- Analyze voltage control and compensation problems in EHV and UHV transmission systems.

Reference Books :

1. Extra High Voltage AC Transmission Engineering – Rakesh Das Begamudre, Wiley Eastern ltd., New Delhi – 1987.
2. EHV Transmission line reference book – Edison Electric Institute (GEC) 1986.

ANALYSIS OF POWER ELECTRONIC CONVERTERS
(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)
(ELECTIVE-I)

Prerequisites: Knowledge on electrical circuit analysis, electronic devices and power electronics.

Course Educational Objectives:

- To understand the control principle of ac to ac conversion with suitable power semi conductor devices.
- To have the knowledge of ac to dc conversion and different ac to dc converter topologies.
- To understand the effect of operation of controlled rectifiers on p.f. and improvement of p.f. with PFC converters
- To acquire the knowledge on dc-ac converters and to know the different control techniques of dc-ac converters.
- To know multilevel inverter configuration to improve the quality of the inverter output voltage.

Unit-1 :AC voltage Controllers
Single Phase AC Voltage Controllers with RL and RLE loads-ac voltage controller's with PWM control-Effects of source and load inductances –synchronous tap changers –Application-numerical problems
Three Phase AC Voltage controllers-Analysis of Controllers with star and delta connected resistive, resistive –inductive loads-Effects of source and load inductances–Application-numerical problems.

Unit –2: AC-DC converters
Single phase Half controlled and Fully controlled Converters with RL load– Evaluation of input power factor and harmonic factor-Continuous and Discontinuous load current-Power factor improvements-Extinction angle control-symmetrical angle control-PWM single phase sinusoidal PWM-Single phase series converters- numerical problems. Three Phase ac-dc Converters- Half controlled and fully controlled Converters with RL load– Evaluation of input power factor and harmonic factor-Continuous and Discontinuous load current-three phase dual converters-Power factor improvements-three phase PWM-twelve pulse converters- numerical problems

Unit-3: Power Factor Correction Converters
Single-phase single stage boost power factor corrected rectifier, power circuit principle of operation, and steady state- analysis, three phase boost PFC converter

Unit –4: PWM Inverters
Principle of operation-Voltage control of single phase inverters - sinusoidal PWM – modified PWM – phase displacement Control – Trapezoidal, staircase, stepped, harmonic injection and delta modulation – numerical problems. Voltage Control of Three-Phase Inverters- Sinusoidal PWM- 60^0 PWM- Third Harmonic PWM- Space Vector Modulation- Comparison of PWM Techniques-current source inverters-Variable dc link inverter - numerical problems

Unit 5: Multi level inverters

Introduction, Multilevel Concept, Types of Multilevel Inverters- Diode-Clamped Multilevel Inverter, Principle of Operation, Features of Diode-Clamped Inverter, Improved Diode-Clamped Inverter- Flying-Capacitors Multilevel Inverter- Principle of Operation, Features of Flying-Capacitors Inverter- Cascaded Multilevel Inverter- Principle of Operation- Features of Cascaded Inverter- Switching Device Currents-DC-Link Capacitor Voltage Balancing- Features of Multilevel Inverters- Comparisons of Multilevel Converters

Course Outcomes:

After completion of this course the students will be able to:

- Have the knowledge on principle of ac voltage controller and their control techniques.
- Convert ac voltage to dc voltage and different control strategies of the converter.
- Control the power factor of single phase and three phase ac to dc converters.
- Understand the conversion of dc to ac and their control strategies.
- Analyze different multilevel inverters to improve the quality of the output voltage of the inverter.

Reference books

1. Power Electronics-Md.H.Rashid –Pearson Education Third Edition- First Indian Reprint- 2008
2. Power Electronics- Ned Mohan, Tore M.Undelan and William P.Robbins –John Wiley & Sons -2nd Edition.
3. Power Electronics – Lander –Ed.2009
4. Modern power Electronics and AC Drives – B.K.Bose
5. Power Converter Circuits – William Shepherd & Li Zhang-Yes Dee Publishing Pvt Ltd.

RENEWABLE ENERGY SYSTEMS

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS)

(Elective-I)

Prerequisites: Basic idea of non-conventional energy sources.

Course Educational Objectives:

- To learn basic principle of renewable energy sources.
- To adoption of alternative energy sources for power generation.
- To learn alternative energy sources not based on sun.
- To the adoption and inter connection of renewable and alternative energy sources to grid.

Unit-1

Solar Energy - Availability - Solar radiation data and measurement - Estimation of average solar radiation - Solar water heater types - Heat balance – Flat plate collector efficiency – Efficiency of heat removal - Thermo siphon flow calculation - Forced circulation calculation - Evacuated collectors - Basics of solar concentrators Solar Energy Applications - Solar air heaters – Solar Chimney - Crop driers - Passive solar system - Active solar systems - Water desalination - Output from solar still – Principle of solar ponds.

Unit-2

Wind Energy – Nature of wind – Characteristics – Variation with height and time – Power in wind –Aerodynamics of Wind turbine – Momentum theory – Basics of aerodynamics – Aero foils and their characteristics – HAWT – Blade element theory – Prandtl's lifting line theory (prescribed wake analysis) VAWT aerodynamics – Wind turbine loads – Aerodynamic loads in steady operation – Yawed operation and tower shadow. Wind Energy Conversion System – Siting – Rotor selection – Annual energy output – Horizontal axis wind turbine (HAWT) – Vertical axis wind turbine (VAWT) – Rotor design considerations – Number of blades – Solidity - Blade profile – Upwind/Downwind – Yaw system – Tower – Braking system - Synchronous and asynchronous generators and loads – Integration of wind energy converters to electrical networks – Inverters – Control system – Requirement and strategies – Noise Applications of wind energy

Unit-3

Biomass energy - Bio fuel classification – Examples of thermo chemical, Pyrolysis, biochemical and agrochemical systems – Energy farming – Direct combustion for heat – Process heat and electricity – Ethanol production and use – Anaerobic digestion for biogas – Different digesters – Digester sizing – Applications of Biogas - Operation with I.C.Engine

Unit-4

Ocean Energy - OTEC Principle - Lambert's law of absorption - Open cycle and closed cycle - heat exchanger calculations – Major problems and operational experience. Tidal Power - Principles of power generation - components of power plant – Single and two basin systems – Turbines for tidal power - Estimation of energy – Maximum and minimum power ranges - tidal powerhouse.Wave Energy – Concept of energy and power from waves – Wave characteristics – period and wave velocities - Different wave energy conservation devices (Saltor duck, oscillating water column and dolphin types) – operational experience.

Unit-5

Geothermal Energy - Classification- Fundamentals of geophysics - Dry rock and hot aquifer energy analysis - Estimation of thermal power - Extraction techniques - Prime movers.

Course Outcomes:

Aftercompletion of this course the students will be able to:

- Identify alternate energy sources.
- Classify and analyze different renewable energy systems.
- Adopt different alternate energy sources for power generation.
- Adopt optimally usage of different sources and interconnection with grid.

Reference Books :

1. Renewable Energy Resources / John Twidell and Tony Weir / E &F.N.Spon
2. Renewable Energy Resources Basic Principles and Applications / G.N.Tiwari and M.K.Ghosal / Narosa
3. Solar Energy - Principles of thermal collection and storage/ S.P. Sukhatme / TMH
4. Solar Energy Thermal Processes,/Duffie& Beckman
5. Solar Heating and Cooling / Kreith&Kreider, CRC press.
6. Wind Energy Handbook / Tony Burton, David Sharpe, Nick Jenkins and Ervin Bossanyi / WileyWind Electrical Systems / S.N.Bhadra, D.Kastha and S.Banerjee / Oxford
7. Biogas Technology - A Practical Hand Book / K.Khendelwal& S.S. Mahdi / McGraw-Hill.

ARTIFICIAL INTELLIGENCE TECHNIQUES

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE)

(Elective-I)

Prerequisites: Basic knowledge on human biological systems, concept of optimization and electrical engineering.

Course Educational Objectives:

- To have knowledge on concept of neural network.
- To know different types of neural networks and training algorithms.
- To understand the concept of genetic algorithm and its application in optimization.
- To have the knowledge on fuzzy logic and design of fuzzy logic controllers.
- To know the applications of AI Techniques in electrical engineering.

Unit – 1: Introduction to Neural Networks

Introduction, Humans and Computers, Biological Neural Networks, Historical development of neural network, Terminology and Topology, Biological and artificial neuron models, Basic learning laws.

Unit- 2:Feed Forward Neural Networks

Introduction, Perceptron models: Discrete, continuous and multi-category, Training algorithms: Discrete and Continuous Perceptron Networks, Perceptron convergence theorem, Limitations and applications of the Perceptron model, Generalized delta learning rule, Feedforward recall and error back propagation training-Radial basis function algorithms-Hope field networks

Unit -3: Genetic algorithms &Modelling-introduction-encoding-fitness function-reproduction operators-genetic operators-cross over and mutation-generational cycle-convergence of genetic algorithm

Unit – 4:Classical and Fuzzy Sets

Introduction to classical sets - properties, operations and relations; Fuzzy sets, membership, Uncertainty, operations, properties, fuzzy relations, cardinalities, membership functions.
Fuzzy Logic System Components-Fuzzification, Membership value assignment, development of rule base and decision making system, defuzzification to crisp sets, defuzzification methods.

Unit 5: Application of AI Techniques-load forecasting-load flow studies-economic load dispatch-load frequency control-reactive power control-speed control of dc and ac motors

Course Outcomes:

After completion of this course the students will be able to:

- Understand neural networks and analyze different types of neural networks.
- Design training algorithms for neural networks.
- Develop algorithms using genetic algorithm for optimization.
- Analyze and designfuzzy logic systems.
- Apply AI Techniques in electrical engineering.

Reference Books :

1. Neural Networks, Fuzzy logic, Genetic algorithms: synthesis and applications by RajasekharanandPai – PHI Publication.
2. Introduction to Artificial Neural Systems - Jacek M. Zuarda, Jaico Publishing House, 1997.

I Year - I Semester	L	P	C
	4	0	3

POWER SYSTEM SECURITY

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES)

(ELECTIVE II)

Prerequisites: Basic knowledge of measurements in power systems.

Course Educational Objectives:

- To study the short circuit analysis of balanced and unbalanced power systems.
- To study the power system security analysis.
- To study the real time control of power system.
- To study the principles and applications of SCADA.

Unit-1: Short circuit analysis techniques in AC power Systems- Simulation of short circuit and open circuit faults using network theorems- fixed impedance short circuit analysis techniques-time domain short circuit analysis in large scale power systems- analysis of time variation of AC and DC short circuit components

Unit-2: Fixed impedance Short circuit analysis of large scale power systems-general analysis of balanced, unbalanced and open circuit faults- 3-phase short circuit analysis in large scale power systems, Network equivalents and practical short circuit current assessments in large scale Ac power systems-general studies- uncertainties in short circuit current calculations-probabilistic Short circuit analysis

Unit-3: Risk assessment and safety considerations-control and limitation of high short circuit currents-limitation of short circuit currents in power system operation, design and planning, Types of short circuit fault current limiters- earthing resistor or reactor connected to transformer neutral-pyrotechnic fault current limiters- series resonant current limiters- saturable reactor limiters-other types of fault current limiters and their applications.

Unit-4: Power System Securityanalysis- concept of security- security analysis and monitoring-factors affecting power system security- detection of network problems –overview, contingency analysis for generator and line outages by ILPF method – fast decoupled inverse Lemma-based approach, network sensitivity factors –contingency selection –concentric relaxation and bounding.

Unit-5: Computer control power systems – need for real time and computer control of power systems- operating states of power system – SCADA- implementation considerations – software requirements for implementing above functions.

Course Outcomes:
After completion of this course the students will be able to:

- Analyze the balanced and unbalanced power system under short circuit conditions.
- Understand how to minimize the short circuit effect on the power System.
- Design the power system with more security with real time control.
- Implant SCADA for power system security.

Reference Books:

1.Allen J. Wood and Bruce Woolenberg: Power System Generation, Operation and Control ,John Willey and sons,1996

2.John J.Grainger and William D Stevenson Jr.: Power System analysis,McGraw Hill,ISE,1994.

3.Nasser D.Tleis : Power System Modelling and fault analysis, Elsevier, 2008.

4. Hand book of Power Systems, GrigsBee.,CRC Press ,Newyork.

ADVANCED DIGITAL SIGNAL PROCESSING

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE)

(Elective II)

Prerequisites: Knowledge on signal processing and Z-transform.

Course Educational Objectives:

- To have knowledge on structures of different digital filters.
- To design digital filters with different techniques.
- To understand the implementation aspects of digital filters.
- To analyze the effect of finite word length in signal processing.
- To understand power spectrum estimation techniques in signal processing.

UNIT-1: Digital Filter Structure

Block diagram representation-Equivalent Structures-FIR and IIR digital filter Structures All pass Filters-tunable IIR Digital Filters-IIR tapped cascaded Lattice Structures-FIR cascaded Lattice structures-Parallel-Digital Sine-cosine generator-Computational complexity of digital filter structures.

UNIT-2: Digital filter design

Preliminary considerations-Bilinear transformation method of IIR filter design-design of Low pass high pass-Band pass, and Band stop- IIR digital filters-Spectral transformations of IIR filters, FIR filter design-based on Windowed Fourier series- design of FIR digital filters with least –mean- Square-error-constrained Least-square design of FIR digital filters

UNIT-3: DSP algorithm implementation

Computation of the discrete Fourier transform- Number representation-Arithmetic operations-handling of overflow-Tunable digital filters-function approximation.

UNIT-4 : Analysis of finite Word length effects

The Quantization process and errors- Quantization of fixed -point and floating -point Numbers-Analysis of coefficient Quantization effects - Analysis of Arithmetic Round-off errors, Dynamic range scaling-signal- to- noise ratio in Low -order IIR filters-Low-Sensitivity Digital filters-Reduction of Product round-off errors using error feedback-Limit cycles in IIR digital filters-Round-off errors in FFT Algorithms.

UNIT 5: Power Spectrum Estimation

Estimation of spectra from Finite Duration Observations signals – Non-parametric methods for power spectrum Estimation – parametric method for power spectrum Estimation, Estimation of spectral form-Finite duration observation of signals-Non-parametric methods for power spectrum estimation-Walsh methods-Blackman & torchy method.

Course Outcomes:

After completion of this course the students will be able to:

- Describe structure of digital filters.
- Design digital filters with different techniques.
- Understand the implementation aspects of signal processing algorithms.
- Know the effect of finite word length in signal processing.
- Analyze different power spectrum estimation techniques.

Reference Books:

1. Digital signal processing-sanjit K. Mitra-TMH second edition
2. Discrete Time Signal Processing – Alan V.Oppenheim, Ronald W.Shafer - PHI-1996 1st edition-9th reprint
3 Digital Signal Processing principles, algorithms and Applications – John G.Proakis -PHI –3rd edition-2002
4. Digital Signal Processing – S.Salivahanan, A.Vallavaraj, C. Gnanapriya – TMH - 2nd reprint-2001
5. Theory and Applications of Digital Signal Proceesing-LourensR. Rebinar&Bernold
6. Digital Filter Analysis and Design-Auntonian-TMH

GENERATION & MEASUREMENTS OF HIGHVOLTAGES

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE)

(Elective II)

Prerequisites: Basics of Electrical circuits, Electronics and measurements for testing purpose

Course Educational Objectives:

- To study the numerical methods for analyzing electrostatic field problems.
- To study the fundamental principles of generation of high voltage for testing.
- To study the methods for measurement of high AC ,DC and transient voltages.
- To Study the measurement techniques for high AC ,DC and impulse currents.

Unit 1- Electrostatic fields and field stress control : Electric fields in homogeneous Isotropic materials and in multi dielectric media-Simple configurations-field stress control. Methods of computing electrostatic fields-conductive analogues-Impedance networks Numerical techniques-finite difference method-finite element method and charge simulation method.

Unit 2-Generation of High AC & DC Voltages:

Direct Voltages : AC to DC conversion methods electrostatic generators-Cascaded Voltage Multipliers.

Alternating Voltages : Testing transformers-Resonant circuits and their applications, Tesla coil.

Unit 3-Generation of Impulse Voltages :

Impulse voltage specifications-Impulse generations circuits-Operation, construction and design of Impulse generators-Generation of switching and long duration impulses.

Impulse Currents : Generation of High impulse currents and high current pulses.

Unit 4- Measurement of High AC & DC Voltages :

Measurement of High D.C. Voltages : Series resistance meters, voltage dividers and generating voltmeters.

Measurement of High A.C. Voltages : Series impedance meters electrostatic voltmeters potential transformers and CVTS-voltage dividers and their applications.

Unit 5-Measurement of Peak Voltages : Sphere gaps, uniform field gaps, rod gaps.Chubb-Fortesque methods. Passive and active rectifier circuits for voltage dividers.

Measurement of Impulse Voltages : Voltage dividers and impulse measuring systems-generalized voltage measuring circuits-transfer characteristics of measuring circuits-L.V. Arms for voltage dividers-compensated dividers.

Measurement of Impulse Currents : Resistive shunts-current transformers-Hall Generators and Faraday generators and their applications-Impulse Oscilloscopes.

Course Outcomes:

Aftercompletion of this course the students will be able to:

- Understand numerical computation of electrostatic problems.
- Understand the techniques of generation of high AC, DC and transient voltages.
- Measure high AC, DC and transient voltages.
- Measure high AC, DC and transient currents.

Reference Books :

1. High Voltage Engineering – by E.Kuffel and W.S.Zaengl. Pergaman press Oxford, 1984.
2. High Voltage Engineering – by M.S.Naidu and V.Kamaraju, Mc.Graw-Hill Books Co., New Delhi, 2nd edition, 1995.
3. High Voltage Technology – LL Alston, Oxford University Press 1968.
4. High Voltage Measuring Techniques – A. Schwab MIT Press, Cambridge,USA, 1972.
5. Relevant I.S. and IEC Specifications.

PROGAMMABLE LOGIC CONTROLLERS & APPLICATIONS

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES)

(Elective II)

Prerequisites: Knowledge on relay logic and digital electronics.

Course Educational Objectives:

- To have knowledge on PLC.
- To acquire the knowledge on programming of PLC.
- To understand different PLC registers and their description.
- To have knowledge on data handling functions of PLC.
- To know how to handle analog signal and converting of A/D in PLC.

Unit 1:

PLC Basics: PLC system, I/O modules and interfacing, CPU processor, programming equipment, programming formats, construction of PLC ladder diagrams, devices connected to I/O modules.

Unit 2:

PLC Programming: Input instructions, outputs, operational procedures, programming examples using contacts and coils. Drill press operation. Digital logic gates, programming in the Boolean algebra system, conversion examples. Ladder diagrams for process control: Ladder diagrams and sequence listings, ladder diagram construction and flow chart for spray process system.

Unit 3:

PLC Registers: Characteristics of Registers, module addressing, holding registers, input registers, output registers. PLC Functions: Timer functions and Industrial applications, counters, counter function industrial applications, Arithmetic functions, Number comparison functions, number conversion functions.

Unit 4:

Data Handling functions: SKIP, Master control Relay, Jump, Move, FIFO, FAL, ONS, CLR and Sweep functions and their applications. Bit Pattern and changing a bit shift register, sequence functions and applications, controlling of two axis and three axis Robots with PLC, Matrix functions.

Unit 5:

Analog PLC operation: Analog modules and systems, Analog signal processing, multi bit data processing, analog output application examples, PID principles, position indicator with PID control, PID modules, PID tuning, PID functions.

Course Outcomes:

After completion of this course the students will be able to:

- Understand the PLCs and their I/O modules.
- Develop control algorithms to PLC using ladder logic etc.
- Manage PLC registers for effective utilization in different applications.
- Handle data functions and control of two axis and their axis robots with PLC.
- Design PID controller with PLC.

Reference Books:

1. Programmable Logic Controllers – Principle and Applications by John W. Webb and Ronald A. Reiss, Fifth Edition, PHI
2. Programmable Logic Controllers – Programming Method and Applications by JR. Hackworth and F.D Hackworth Jr. – Pearson, 2004.
3. Introduction to Programmable Logic Controllers- Gary Dunning-Cengage Learning.
4. Programmable Logic Controllers –W.Bolton-Elsevier publisher

MODERN CONTROL THEORY

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

(ELECTIVE-II)

Prerequisites: Control Systems, differential equations.

Course Educational Objectives:

- To facilitate the evolution of state variable approach for the analysis of control systems.
- To examine the importance of controllability and observability in modern control engineering.
- To enable students to analyze various types of nonlinearities & construction of trajectories using describing functions and phase plane analysis.
- To study the analysis of stability and instability of continuous time invariant system

Unit –1: State Variable Analysis

The concept of state – State Equations for Dynamic systems – State diagram - Linear Continuous time model for physical systems – Existence and Uniqueness of Solutions to Continuous – Time State Equations – Solutions – Linear Time Invariant Continuous – Time State Equations – State transition matrix and it's properties

Unit – 2: State Variable Techniques

General concept of Controllability - General concept of Observability Controllability tests for Continuous &Time Invariant systems - Observability tests for Continuous &Time Invariant systems - Controllability and Observability of state model in Jordan Canonical form - Controllability and Observability Canonical forms of State model – State feedback controller design through pole assignment.

Unit – 3: Non Linear Systems – I

Introduction – Non Linear Systems – Types of Non – Linearities – Saturation – Dead – Zone – Backlash – Jump Phenomenon etc; - Singular Points – Introduction to Linearization of nonlinear systems, properties of Non Linear Systems – Describing function – describing function analysis of nonlinear systems- Stability analysis of Non – Linear systems through describing functions.

Unit – 4: Non Linear Systems – II

Introduction to phase – plane analysis, Method of Isoclines for Constructing Trajectories, singular points, phase – plane analysis of nonlinear control systems.

Unit – 5: Stability Analysis

Stability in the sense of Lyapunov, Lyapunov's stability and Lyapunov's instability theorems – Stability Analysis of the Linear Continuous time invariant systems by Lyapunov second method – Generation of Lyapunov functions – Variable gradient method – Krasooviski's method.

Course Outcomes:

After completion of this course the students will be able to:

- Understanding the state variable approach is suitable for higher order.
- To analyze the concepts of controllability and observability.
- To analyze the various non-linearities through describing functions and phase plane analysis.
- Typical issues of stability and instability of continuous time invariant systems.

Reference Books :

1. Modern Control System Theory by M. Gopal – New Age International – 1984
2. Modern Control Engineering by Ogata. K – Prentice Hall – 1997
3. Nonlinear systems, Hassan K. Klalil, Prentice Hall, 1996
4. Modern control systems, Richard C. Dorf and Robert H. Bishop, 11th Edition, Pearson Edu, India, 2009

I Year - I Semester

	L	P	C
	0	4	2

SIMULATION LABORATORY

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES)

Course Educational Objectives:

To understand the modeling of various aspects of Power System analysis and develop the MATLAB programming.

List of Experiments:

1. Formation of Y- Bus by Direct-Inspection Method.
2. Load Flow Solution Using Gauss Siedel Method
3. Load Flow Solution Using Newton Raphson Method
4. Load Flow Solution UsingFast Decoupled Method
5. Formation of Z-Bus by Z-bus building algorithm
6. Symmetrical Fault analysis using Z-bus
7. Unsymmetrical Fault analysis using Z-bus
8. Economic Load Dispatch with & without transmission losses
9. Transient Stability Analysis Using Point By Point Method
10. Load FrequencyControlofSingleArea Control& Two AreaControlsystem with and without controllers.

Course Outcomes:

After the completion of the lab they will verify the theoretical concepts of various aspects of Power System analysis.

I Year - II Semester	L	P	C
	4	0	3

POWER SYSTEM DYNAMICS AND STABILITY

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES)

Prerequisites: Knowledge of synchronous machine, Power System Analysis

Course Educational Objectives:

- To study the model of synchronous machines.
- To study the stability studies of synchronous machines.
- To study the solution method of transient stability.
- To study the effect of different excitation systems.

Unit 1 : System Dynamics : Synchronous machine model in state space from computer representation for excitation and governor system –modeling of loads and induction machines.

Unit 2: Steady state stability – steady state stability limit – Dynamics Stability limit – Dynamic stability analysis – State space representation of synchronous machine connected to infinite bus-time response – Stability by eighvalue approach.

Unit 3: Digital Simulation of Transient Stability : Swing equation machine equations – Representation of loads – Alternate cycle solution method – Direct method of solution – Solution Techniques : Modified Euler method – RungeKutta method – Concept of multi machine stability.

Unit 4: Effect of governor action and excite on power system stability effect of saturation, saliency & automatic voltage regulators on stability.

Unit 5: Excitation Systems : Rotating Self-excited Exciter with direct acting Rheostatic type voltage regulator – Rotating main and Pilot Exciters with Indirect Acting Rheostatic Type Voltage Regulator – Rotating Main Exciter, Rotating Amplifier and Static Voltage Regulator – Static excitation scheme – Brushless excitation system.

Course Outcomes:

Aftercompletion of this course the students will be able to:

- Able to determine the model of synchronous machines.
- Able to know the stability studies of synchronous machines.
- Able to get the knowledge of solution methods of transient stability.
- Able to know the effect of different excitation systems in power systems.

Reference Books :

1. Power System Stability by Kimbark Vol. I&II, III, Willey.
2. Power System control and stability by Anderson and Fund, IEEE Press.
3. Power systems stability and control by PRABHA KUNDUR, TMH.
4. Computer Applications to Power Systems–Glenn.W.Stagg& Ahmed. H.El.Abiad, TMH.
5. Computer Applications to Power Systems – M.A.Pai, TMH.
6. Power Systems Analysis & Stability – S.S.VadheraKhanna Publishers

I Year - II Semester

L	P	C
4	0	3

FLEXIBLE AC TRANSMISSION SYSTEMS

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE, PE&PS)

Prerequisites: Concepts onPower Electronics and Power Systems

Course Educational Objectives:

- To study the performance improvements of transmission system with FACTS.
- To study the effect of static shunt compensation.
- To study the effect of static series compensation.
- To study the effect of UPFC.

Unit 1 : FACTS concepts, Transmission interconnections, power flow in an AC System, loading capability limits, Dynamic stability considerations, importance of controllable parameters, basic types of FACTS controllers, benefits from FACTS controllers.

Unit 2 : Basic concept of voltage and current source converters, comparison of current source converters with voltage source converters.

Static shunt compensation : Objectives of shunt compensation, midpoint voltage regulation, voltage instability prevention, improvement of transient stability, Power oscillation damping, methods of controllable var generation, variable impedance type static var generators, switching converter type var generators, hybrid var generators.

Unit 3 :SVC and STATCOM : The regulation and slope transfer function and dynamic performance, transient stability enhancement and power oscillation damping, operating point control and summary of compensation control.

Unit 4 : Static series compensators : Concept of series capacitive compensation, improvement of transient stability, power oscillation damping, functional requirements. GTO thyristor controlled series capacitor (GSC), thyristor switched series capacitor (TSSC), and thyristor controlled series capacitor (TCSC), control schemes for GSC, TSSC and TCSC.

Unit 5 : Unified Power Flow Controller: Basic operating principle, conventional transmission control capabilities, independent real and reactive power flow control, comparison of the UPFC to series compensators and phase angle regulators.

Course Outcomes:
After completion of the course, the student will be able to:

- Know the performance improvement of transmission system with FACTS.
- Get the knowledge of effect of static shunt and series compensation.
- Know the effect of UPFC.
- Determine an appropriate FACTS device for different types of applications.

Reference Books :

1. "Understanding FACTS Devices" N.G.Hingorani and L.Guygi, IEEE Press.
   Indian Edition is available:--Standard Publications
2. Sang.Y.H and John.A.T, "Flexible AC Transmission systems" IEEE Press (2006).
3. HVDC & FACTS Controllers: applications of static converters in power systems- Vijay K.Sood- Springer publishers

I Year - II Semester

L	P	C
4	0	3

REAL TIME CONTROL OF POWER SYSTEMS

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES)

Prerequisites: Power system operation and control.

Course Educational Objectives:

- To understand the importance of state estimation in power systems.
- To know the importance of security and contingency analysis.
- To understand SCADA, its objectives and its importance in power systems.
- To know the significance of voltage stability analysis.
- To know the applications of AI to power systems problems.

Unit 1 : State Estimation : Different types of State Estimations, Theory of WLS state estimation, sequential and non-sequential methods to process measurements. Bad data Observability, Bad data detection, identification and elimination.

Unit 2 : Security and Contingency Evaluation : Security concept, Security Analysis and monitoring, Contingency Analysis for Generator and line outages by iterative linear power flow method, Fast Decoupled model, and network sensitivity methods.

Unit 3 : Computer Control of Power Systems : Need for real time and computer control of power systems, operating states of a power system, SCADA - Supervisory control and Data Acquisition systems implementation considerations, energy control centres, software requirements for implementing the above functions.

Unit 4 : Voltage Stability, voltage collapse, and voltage security, relation of voltage stability to rotor angle stability. Voltage stability analysis Introduction to voltage stability analysis `P-V' curves and `Q-V' curves, voltage stability in mature power systems, long-term voltage stability, power flow analysis for voltage stability, voltage stability static indices and Research Areas.

Unit 5 : Application of AI and ANN in Power System : Basic concepts and definitions, algorithms for load flow, short term load forecasting, fault diagnosis and state estimation.

Course Outcomes:

Aftercompletion of this course the students will be able to:

- Understand state estimation, security and contingency evaluation.
- Understand about Supervisory control and data acquisition.
- Real time software application to state estimation.
- Understand application of AI in power system.

Reference Books :

1. John J.Grainger and William D.Stevenson, Jr. : Power System Analysis, McGraw-Hill, 1994, International Edition
2. Allen J.Wood and Bruce F.Wollenberg : Power Generation operation and control, John Wiley & Sons, 1984
3. R.N.Dhar : Computer Aided Power Systems Operation and Analysis, Tata McGraw Hill, 1982
4. L.P.Singh : Advanced Power System Analysis and Dynamics, Wiley Eastern Ltd. 1986
5. PrabhaKundur : Power System Stability and Control -, McGraw Hill, 1994
6. P.D.Wasserman : `Neural Computing : Theory and Practice' Van Nostrand - Feinhold, New York.

I Year - II Semester

	L	P	C
	4	**0**	**3**

ADVANCED POWER SYSTEM PROTECTION

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE, PE&PS)

Prerequisites: Concepts of Power Electronics, Electronic circuits, STLD and basics of Relays and protection.

Course Educational Objectives:

- To learn about classification and operation of static relays.
- To understand the basic principles and application of comparators.
- To learn about static version of different types of relays.
- To understand about numerical protection techniques.

Unit 1 : Static Relays classification and Tools : Comparison of Static with Electromagnetic Relays, Basic classification, Level detectors and Amplitude and phase Comparators – Duality – Basic Tools – Schmitt Trigger Circuit, Multivibrators, Square wave Generation – Polarity detector – Zero crossing detector – Thyristor and UJT Triggering Circuits. Phase sequence Filters – Speed and reliability of static relays.

Unit 2 : Amplitude and Phase Comparators (2 Input) : Generalized equations for Amplitude and Phase comparison – Derivation of different characteristics of relays – Rectifier Bridge circulating and opposed voltage type amplitude comparators – Averaging & phase splitting type amplitude comparators – Principle of sampling comparators.

Phase Comparison : Block Spike and phase Splitting Techniques – Transistor Integrating type, phase comparison, Rectifier Bridge Type Comparison – Vector product devices.

Unit 3 : Static over current (OC) relays – Instantaneous, Definite time, Inverse time OC Relays, static distance relays, static directional relays, static differential relays, measurement of sequence impedances in distance relays, multi input comparators, elliptic & hyperbolic characteristics, switched distance schemes, Impedance characteristics during Faults and Power Swings,

Unit 4 : PILOT Relaying schemes: Wire pilot protection: circulating current scheme – balanced voltage scheme – translay scheme – half wave comparison scheme - carrier current protection: phase comparison type – carrier aided distance protection – operational comparison of transfer trip and blocking schemes – optical fibre channels.

Unit 5 : Microprocessor based relays andNumerical Protection: Introduction – over current relays – impedance relay – directional relay – reactance relay.

Numerical Protection: Introduction - numerical relay - numerical relaying algorithms - mann-morrison technique - Differential equation technique and discrete fourier transform technique - numerical over current protection - numerical distance protection.

Course Outcomes:

After completion of this course the students will be able to:

- Know the classifications and applications of static relays.
- Understand the application of comparators.
- Understand the static version of different types of relays.
- Understand the numerical protection techniques.

Reference Books :

1. Power System Protection with Static Relays – by TSM Rao, TMH.
2. Protective Relaying Vol-II Warrington, Springer.
3. Art & Science of Protective Relaying - C R Mason, Willey.
4. Power System Stability KimbarkVol-II, Willey.
5. Power system protection & switchgear by Badri Ram & D N viswakarma, TMH.
6. Electrical Power System Protection –C.Christopoulos and A.Wright- Springer
7. Protection & Switchgear –BhaveshBhalaja,R.PMaheshwari, NileshG.Chothani-Oxford publisher

I Year - II Semester	L	P	C
	4	0	3

SMART GRID TECHNOLOGIES

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS, PE, P&ID, PE&ED, PE&D, PE&S, EM&D)

(Elective – III)

Prerequisites: Basic knowledge on smart concept communication protocols, renewable energy systems and electronic circuits.

Course Educational Objectives:

- To understand concept of smart grid and developments on smart grid.
- To understand smart grid technologies and application of smart grid concept in hybrid electric vehicles etc.
- To have knowledge on smart substations, feeder automation and application for monitoring and protection.
- To have knowledge on micro grids and distributed energy systems.
- To know power quality aspects in smart grid.

Unit 1

Introduction to Smart Grid: Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid, Concept of Resilient &Self Healing Grid, Present development & International policies on Smart Grid. Case study of Smart Grid.

Unit 2

Smart Grid Technologies: Part 1: Introduction to Smart Meters, Real Time Prizing, Smart Appliances, Automatic Meter Reading(AMR), Outage Management System(OMS), Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation, Phase Shifting Transformers.

Unit 3

Smart Grid Technologies: Part 2: Smart Substations, Substation Automation, Feeder Automation. Geographic Information System(GIS), Intelligent Electronic Devices(IED) & their application for monitoring & protection, Smart storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage, Wide Area Measurement System(WAMS), Phase Measurement Unit(PMU).

Unit 4

Microgrids and Distributed Energy Resources: Concept of micro grid, need & applications of microgrid, formation of microgrid, Issues of interconnection, protection & control of microgrid. Plastic & Organic solar cells, Thin film solar cells, Variable speed wind generators, fuelcells, microturbines, Captive power plants, Integration of renewable energy sources.

Unit 5

Power Quality Management in Smart Grid: Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.

Information and Communication Technology for Smart Grid: Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN).

Course Outcomes:

After completion of this course the students will be able to:

- Understand smart grids and analyse the smart grid policies and developments in smart grids.
- Develop concepts of smart grid technologies in hybrid electrical vehicles etc.
- Understand smart substations, feeder automation, GIS etc.
- Analyse micro grids and distributed generation systems.
- Analyse the effect of power quality in smart grid and to understand latest developments in ICT for smart grid.

Text Books:

1. Ali Keyhani, Mohammad N. Marwali, Min Dai “Integration of Green and Renewable Energy in Electric Power Systems”, Wiley
2. Clark W. Gellings, “The Smart Grid: Enabling Energy Efficiency and Demand Response”,CRC Press
3. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama,“Smart Grid: Technology and Applications”, Wiley
4. Jean Claude Sabonnadière, NouredineHadjsaïd, “Smart Grids”, Wiley Blackwell 19
5. Peter S. Fox Penner, “Smart Power: Climate Changes, the Smart Grid, and the Future of Electric Utilities”, Island Press; 1 edition 8 Jun 2010
6. S. Chowdhury, S. P. Chowdhury, P. Crossley, “Microgrids and Active Distribution Networks.” Institution of Engineering and Technology, 30 Jun 2009
7. Stuart Borlase, “Smart Grids (Power Engineering)”, CRC Press

Reference Books:

1. Andres Carvallo, John Cooper, “The Advanced Smart Grid: Edge Power Driving Sustainability: 1”, Artech House Publishers July 2011
2. James Northcote, Green, Robert G. Wilson “Control and Automation of Electric Power Distribution Systems (Power Engineering)”, CRC Press
3. MladenKezunovic, Mark G. Adamiak, Alexander P. Apostolov, Jeffrey George Gilbert “Substation Automation (Power Electronics and Power Systems)”, Springer
4. R. C. Dugan, Mark F. McGranghan, Surya Santoso, H. Wayne Beaty, “Electrical Power System Quality”, 2nd Edition, McGraw Hill Publication
5. Yang Xiao, “Communication and Networking in Smart Grids”, CRC Press

POWER QUALITY
(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES)
(Elective III)

Prerequisites: Knowledge on electric circuit analysis, power systems and power electronics.

Course Educational Objectives:

- To understand significance of power quality and power quality parameters.
- To know types of transient over voltages and protection of transient voltages.
- To understand harmonics, their effects, harmonic indices and harmonic minimization techniques.
- To understand long duration voltage variation and flicker
- To know power quality aspects in distributed generation.

Unit-1 Introduction
Overview of Power Quality - Concern about the Power Quality - General Classes of Power Quality Problems – Transients -Long-Duration Voltage Variations - Short-Duration Voltage Variations - Voltage Unbalance - Waveform Distortion - Voltage fluctuation - Power Frequency Variations - Power Quality Terms - Voltage Sags and Interruptions - Sources of Sags and Interruptions – Nonlinear loads.

Unit-2 Transient Over Voltages
Source of Transient Over Voltages - Principles of Over Voltage Protection - Devices for Over Voltage Protection - Utility Capacitor Switching Transients - Utility Lightning Protection - Load Switching Transient Problems - Computer Tools for Transient Analysis

Unit-3 Harmonic Distortion and solutions
Voltage vs. Current Distortion - Harmonics vs. Transients - Power System Quantities under Nonsinusoidal Conditions - Harmonic Indices – Sources of harmonics - Locating Sources of Harmonics – System Response Characteristics - Effects of Harmonic Distortion – Interharmonics - Harmonic Solutions Harmonic Distortion Evaluation - Devices for Controlling Harmonic Distortion - Harmonic Filter Design - Standards on Harmonics

Unit- 4 Long Duration Voltage Variations
Principles of Regulating the Voltage - Device for Voltage Regulation - Utility Voltage Regulator Application - Capacitor for Voltage Regulation - End-user Capacitor Application - Regulating Utility Voltage with Distributed Resources – Flicker

Unit-5 Distributed Generation and Power Quality
Resurgence of Distributed Generation - DG Technologies - Interface to the Utility System - Power Quality Issues - Operating Conflicts - DG on Low Voltage Distribution Networks - Interconnection standards - Wiring and Grounding - Typical Wiring and Grounding Problems - Solution to Wiring and grounding Problems

Course Outcomes:

After completion of this course the students will be able to:

- Have the knowledge on causes of power quality, power quality parameters.
- Understand sources of transient over voltages and providing protection to transient over voltages.
- Understand effects of harmonics, sources of harmonics and harmonic minimization.
- Analyze long duration voltage variations and regulation of voltage variations.
- Describe power quality aspects in distributed generation and develop solutions to wiring and grounding problems.

Reference Books :

1. Electrical Power Systems Quality, Dugan R C, McGranaghan M F, Santoso S, and Beaty H W, Second Edition, McGraw-Hill, 2002.
2. Power Quality Primer, Kennedy B W, First Edition, McGraw-Hill, 2000.
3. Understanding Power Quality Problems: Voltage Sags and Interruptions, Bollen M H J, First Edition, IEEE Press; 2000.
4. Power System Harmonics, Arrillaga J and Watson N R, Second Edition, John Wiley & Sons, 2003.
5. Electric Power Quality control Techniques, W. E. Kazibwe and M. H. Sendaula, Van Nostrad Reinhold, New York.
6. Power Quality c.shankaran, CRC Press, 2001
7. Harmonics and Power Systems –Franciso C.DE LA Rosa-CRC Press (Taylor & Francis)
8. Power Quality in Power systems and Electrical Machines-EwaldF.fuchs, Mohammad A.S. Masoum-Elsevier

POWER SYSTEM RELIABILITY

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES,PE&PS)

(Elective – III)

Prerequisites: Probability theory, power systems.

Course Educational Objectives:

- Will be able to get the basic understanding of network modelling and reliability.
- Markov chains.
- Reliability analysis of generation systems.
- Decomposition techniques.

Unit 1 : Basic probability theory – rules for combining probabilities of events – Bernoulli`s trials – probability density and distribution functions – binomial- distributions – expected value and standard deviation of binomial distribution.

Unit 2 : Network Modelling and Reliability Analysis of Series, Parallel, Series-Parallel networks – complex networks – decomposition method
Reliability functions F(t), F(t), R(t), h(t) and their relationship – exponential distributions – Expected value and standard deviation of exponentional distribution – Bath tub curve – reliability analysis of series parallel networks using exponential distribution – reliability measures MTTF, MTTR, MTBF

Unit 3 : Markov chains – concept of stochastic transitional probability Matrix, Evaluation of limiting state Probabilities – Markov processes one component repairable system – time dependent probability evaluation using Laplace transform approach – evaluation of limiting state probabililties using STPM – two component repairable models – Frequency and duration concept – Evaluation of frequency of encountering state, mean cycletime, for one, two component repairable models – evaluation of cumulative probability and cumulative frequency of encountering merged states

Unit 4 : Generation system reliability analysis – reliability model of a generation system – recursive relation for unit addition and removal – load modelling – merging of generation load model – evaluation of transition rates for merged state model – cumulative Probability, cumulative frequency of failure evaluation – LOLP, LOLE.

Unit 5 : Composite system reliability analysis decomposition method – distribution system reliability analysis – radial networks – weather effects on transmission lines – Evaluation of load and energy indices.

Course Outcomes:

After completion of this course the students will be able to:

- Understand reliability analysis applied to power systems.
- Understand Markov Chains and application to power systems.
- Perform stability analysis of generation systems.
- Understand decomposition techniques applied to power system.

Reference Books :

1. Reliability Evaluation of Engg. System – R.Billinton, R.N.Allan, Plenum Press, New York.
2. Reliability Evaluation of Power System – R.Billinton, R.N.Allam, Plenum Press, New York
3. An Introduction to Realiability and Maintainability Engineering. Sharies E Ebeling, TATA McGraw Hill – Edition

VOLTAGE STABILITY
(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, PE&PS)
(Elective III)

Prerequisites: Basic concepts of power system analysis and power factor correction.

Course Educational Objectives:
- To study the importance of voltage stability.
- To study the various load modelling in power system.
- To study the effect of reactive power compensation and voltage control.
- To study the modelling of voltage stability static indices.
- To study the voltage stability margin and its improvement.

Unit 1 : Reactive Power flow and voltage stability in power systems: Physical relationship indicating dependency of voltage on reactive power flow - reactive power, transient stability; Q-V curve; definition of voltage stability, voltage collapse and voltage security. Voltage collapse phenomenon, Factors of voltage collapse, effects of voltage collapse, voltage collapse analysis.

Unit 2 : Power system loads : Load characteristics that influence voltage stability such as – Discharge lighting, Induction motor, Air conditioning and heat pumps, Electronic power supplies, Over Head lines and cables.

Unit 3 : Reactive Power compensation : Generation and absorption of reactive power – Reactive power compensators & voltage controllers : - shunt capacitors, synchronous phase modifier – static VAR system – on load tap changing transformer, booster transformers.

Unit 4 : Voltage stability static indices : Development of voltage collapse index – power flow studies – singular value decomposition – minimum singular value of voltage collapse – condition number as voltage collapse index.

Unit 5 :voltage stability margins & Improvement of voltage stability: Stability margins, voltage stability margin of un compensated and compensated power system . Dynamic voltage stability – voltage security , Methods of improving voltage stability and its practical aspects.

Course Outcomes:
Aftercompletion of this course the students will be able to:
- Know the importance of voltage stability.
- Determine the load modelling of power systems.
- Get the knowledge of reactive power compensation and voltage control.
- Determine the modelling of static voltage stability indices.
- Know the voltage stability margin and its improvement.

Reference Books :

3. Performance operation and control of EHV power transmission Systems A. chakrabarti, D.P.Kothari, A.K. Mukhopadhyay, A.H. Wheeler publishing, 1995.
4. Power system Voltage stability - C.W. Taylor , Mc. Graw Hill, 1994

I Year - II Semester	L	P	C
	4	0	3

POWER SYSTEM DEREGULATION

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE PE&PS)

(Elective IV)

Prerequisites: Knowledge on power systems

Course Educational Objectives:

- To provide in-depth understanding of operation of deregulated electricity market systems.
- To examine typical issues in electricity markets and how these are handled world –wide in various markets.
- To enable students to analyze various types of electricity market operational and control issues using new mathematical models.

Unit 1

Need and conditions for deregulation. Introduction of Market structure, Market Architecture, Spot market, forward markets and settlements. Review of Concepts marginal cost of generation, least-cost operation, incremental cost of generation. Power System Operation.

Unit 2

Electricity sector structures and Ownership /management, the forms of Ownership and management. Different structure model like Monopoly model, Purchasing agency model, wholesale competition model, Retail competition model.

Unit 3

Framework and methods for the analysis of Bilateral and pool markets, LMP based markets, auction models and price formation, price based unit commitment, country practices

Unit 4

Transmission network and market power. Power wheeling transactions and marginal costing, transmission costing. Congestion management methods- market splitting, counter-trading; Effect of congestion on LMPs- country practices

Unit 5

Ancillary Services and System Security in Deregulation. Classifications and definitions, AS management in various markets- country practices. Technical, economic, & regulatory issues involved in the deregulation of the power industry.

Course Outcomes:

Aftercompletion of this course the students will be able to:

- Understand of operation of deregulated electricity market systems
- Typical issues in electricity markets
- To analyze various types of electricity market operational and control issues using new mathematical models.

Reference Books:

1. Power System Economics: Designing markets for electricity - S. Stoft, wiley.
2. Power generation, operation and control, -J. Wood and B. F. Wollenberg, Wiley.
3. Operation of restructured power systems - K. Bhattacharya, M.H.J. Bollen and J.E. Daalder, Springer.
4. Market operations in electric power systems - M. Shahidehpour, H. Yaminand Z. Li,Wiley.
5. Fundamentals of power system economics - S. Kirschen and G. Strbac, Wiley.
6. Optimization principles: Practical Applications to the Operation and Markets of the Electric Power Industry - N. S. Rau, IEEE Press series on Power Engineeirng.
7. Competition and Choice in Electricity - Sally Hunt and Graham Shuttleworth, Wiley.

HIGH VOLTAGE TESTING TECHNIQUES

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES, HVE, PSHVE)

(Elective IV)

Prerequisites: Basics of high voltage engineering.

Course Educational Objectives:

- To understand non destructive testing methods.
- To understand commercial and technical testing of different HV power applications.

Unit 1 : Non Destructive Testing Techniques : Measurement of DC Resistivity – Dielectric loss and dielectric constant of insulating materials – Schering bridge method – Transformer ratio arm bridge for high voltage and high current applications – null detectors.

Unit 2 : High Voltage Testing of Power Apparatus : Need for testing standards – Standards for porcelain/Glass insulators-Classification of porcelain/glass insulator tests – Tests for cap and pin porcelain/Glass insulators.

Unit 3 : High voltage AC testing methods-Power frequency tests-Over voltage tests on insulators, Isolators, Circuit Breakers and power cables. Artificial Contamination Tests : Contamination flashover phenomena-Contamination Severity-Artificial contamination tests-Laboratory Testing versus in-Service Performance-Case study.

Unit 4 : Impulse Testing : Impulse testing of transformers, insulators, Surge diverters, Bushings, cables, circuit breakers.

Unit 5 : Partial Discharge Measurement : PD equivalent model-PD currents-PD measuring circuits-Straight and balanced detectors-Location and estimation of PD in power apparatus-PD measurement by non electrical methods-Calibration of PD detectors. RIV Measurements : Radio Interference – RIV – Measurement of RI and RIV in laboratories and in field. Different test arrangements and their limitations.

Course Outcomes:

Aftercompletion of this course the students will be able to:

- Understand different testing procedures on electrical a) Insulating materials b) Insulation Systems. c) Power apparatus.
- Learn the different testing techniques adopted on electrical power apparatus.

Reference Books :

1. High Voltage Engineering – by E.KUFFEL and W.S.ZAENGL, Pergamon press, Oxford 1984.
2. High Voltage Engineering – by M.S.Naidu and V.Kamaraju, Tata McGraw Hill Publishing Company Limited, New Delhi – 2001.
3. Discharge Detection in H.V. Equipment – by KREUGER, F.H. Haywood London – 1964.
4. Hyltencavallius. N. High voltage laboratory planning EnileHaefely&Co. Ltd. Based Switzerland 1988
5. Ryan H.M. and Whiskand: design and operation perspective of British UHV Lab IEE pre 133 H.V. Testing Techniques Halfly

POWER SYSTEM TRANSIENTS

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES)

(Elective IV)

Prerequisites: This course required knowledge of circuit transients, symmetrical components, fault analysis and lightning.

Course Educational Objectives:

- To study the effect of over voltages on power system.
- To study the techniques of travelling wave on transmission lines.
- To study the effect of lightning and switching transients on power systems.

Unit 1 : Basic Concepts and Simple Switching Transients;- Switching an LR,LC,RLC circuits Transients Analysis of Three-Phase power Systems: – Symmetrical components inthree-phase Systems, Sequence Components for Unbalanced Network Impedances, the Sequence Networks, analysis of Unsymmetrical Three-Phase Faults-single line-to-Ground Fault, Three phase-to-ground fault.

Unit 2 : Travelling Waves:- Velocity of Travelling waves and Characteristic Impedance, Energy Contents of Travelling Waves, Attenuation and Distortion of Electromagnetic Waves, telegraph equations-lossless line, distortion less line, Reflection and Refraction of Travelling Waves, Reflection of Travelling Waves against Transformer-and-Generator-windings, the Origin Transient Recovery voltages, bewley-lattice diagram. travelling waves and multi conductor system.

Unit 3 :Switching Transients:- arc interruption in circuit breaker , transient recovery voltage, arc-circuit interaction, interruption of capacitive currents, interruption of inverse currents, interruption of fault current in transmission line and transformers.

Unit 4 : Power System Transient Recovery Voltages:-Characteristics of the Transient Voltage- Short-circuit test duties based on IEC 60056 (1987),ANSI/IEEE Standards, the Harmonization between IEC and ANSI/IEEE Standards with respect to Short-circuit Test duties, transient recovery voltage for Different types of faults.

Unit 5 : Lightning –Induced Transients:-Mechanism of Lightning, wave shape of the lightning current, Direct lighting Stroke to transmission line towers, direct lightening stroke to a line, lightning protection scheme. Numerical simulation of electrical transients, The Electromagnetic Transient Program, principles of numerical techniques used in transient simulation.

Course Outcomes:

Aftercompletion of this course the students will be able to:

- Understand the severity of over voltages due to faults on a given power system.
- To limit the effects of lightning over voltages in power systems.
- Understand the various transient over voltages and their effects on power system.

Reference Books :

1. Electrical Transients in Power System by Allen Greenwood, McGraw Hill 1990
2. Power system grounding & transients by A.P.SakisMeliopolous.
3. "Transients in power systems" by Lou Van Sluis
4. Bewley LV "travelling waves on transmission system" Dover publications Inc.,
5. Walter Diesendorf, Insulation co-ordination in high-voltage electric power systems, Butterworths, London, (1974),
6. J. G. Anderson: EHV Transmission Line Reference Book (Edison Electric Institute, New York, 1968) p. 126.

DEMAND SIDE ENERGY MANAGEMENT

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES)

(Elective IV)

Prerequisites: Students require concepts on utilization of electrical energy.

Course Educational Objectives:

- To know the energy audit principles in power system.
- To know the energy economics associated with consumption of energy.
- To know the energy conservation in electric utility and industry.
- To know the lighting schemes and methods to conserve the energy.
- To understand the energy conservation aspect in space heating, ventilation, air Condition etc.

Unit-1 : Energy Audit and Energy management information systems: Energy audit: Definitions-Need-concepts-Types of energy audit; Energy management information systems: Introduction-Need-components-designing-using the system-identifying plant outages

Unit-2 : Energy Economics: Introduction-Cost benefit risk analysis-Payback period-Straight line depreciation-Sinking fund depreciation—Reducing balance depreciation-Net present value method-Internal rate of return method-Profitability index for benefit cost ratio.

Unit-3 : Energy Conservation in Electric utilities and Industry: Electrical load management: Energy and load management devices-Conservation strategies; conservation in electric utilities and industry: Introduction-Energy conservation in utilities by improving load factor-Utility voltage regulation-Energy conservation in Industries-Power factor improvement.

Energy –efficient electric motors: Energy efficient motors-construction and technical features-case studies of EEMs with respect to cost effectiveness-performance characteristics; Economics of EEMs and system: life cycle-direct savings and payback analysis-efficiency factor or efficiency evaluation factor

Unit-4 : Electric Lighting: Introduction-Need for an energy management program-Building analysis-Modification of existing systems-Replacement of existing systems-priorities:
Illumination requirement : Task lighting requirements-lighting levels-system modifications-non illumination modifications-lighting for non task areas-reflectances-space geometry ;System elements: light sources - characteristics of families of lamps-lamp substitution in an existing systems-selection of Higher efficiency lamps for a new system-Luminaries-ballasts-energy conservation in lighting.

Unit-5 : Space Heating ,Ventilation, Air-Conditioning(HVAC) and Water Heating: Introduction-Heating of buildings-Transfer of Heat-Space heating methods-Ventilation and air-conditioning-Insulation-Cooling load-Electric water heating systems-Energy conservation methods.

Co-generation and storage: Combined cycle cogeneration-energy storage: pumped hydro schemes-compressed air energy storage(CAES)-storage batteries-superconducting magnetic energy storage (SMES).

Course Outcomes:

After completion of this course the students will be able to:

- Understand the principles and application of energy audit.
- Understand energy economics in utility systems.
- Understand the principle of energy conservation in lightning schemes.
- Apply energy audit principles in heating, ventilation and airconditioning etc.

Reference Books :

1.Energy management Hand book by Wayne C.Turner,Johnwiley and sons publications
2.Electric Energy Utilization and Conservation by S C Tripath, TMH publishing company ltd.New Delhi
3.Energy efficient electric motors selection and application by John C.Andreas
4.Hand book on Energy Audit and Management by AmitkumarTyagi,published by TERI(Tata energy research Institute)
5.Energy management by Paul W.O' Callaghan McGraw hill book company
6.Energy conversion systems by Rakosh Das Begamudre New age international publishers.

I Year - II Semester	L	P	C
	0	4	2

POWER SYSTEMS LABORATORY

(Common to PS, PSC&A, PSE, PS&C, APS, EPE, PE&ES)

Course Educational Objectives:

To understand the experimental determination of various parameters used in power system area and to analyse the performance of transmission line with and without compensation.

List of Experiments:

1. Determination of Sequence Impendence of an Alternator by direct method.

2. Determination of Sequence impedance of an Alternator by fault Analysis.

3. Measurement of sequence impedance of a three phase transformer

    (a). by application of sequence voltage.

    (b). using fault analysis.

4. Power angle characteristics of a salient pole Synchronous Machine.

5. Poly-phase connection on three single phase transformers and measurement of phase displacement.

6.Determination of equivalent circuit of 3-winding Transformer.

7. Measurement of ABCD parameters on transmission line model.

8. Performance of long transmission line without compensation.

9. Study of Ferranti effect in long transmission line.

10. Performance of long transmission line with shunt compensation.

Course Outcomes:

After the Completion of lab they will understand procedure for determination of various parameters used in power system as well as performance of transmission line.

II Year - III Semester	L	P	C
	0	0	2

COMPREHENSIVE VIVA-VOCE

II Year - III Semester	L	P	C
	0	0	2

SEMINAR - I

II Year - III Semester	**L**	**P**	**C**
	0	**0**	**16**

PROJECST WORK PART - I

II Year - IV Semester	L	P	C
	0	0	2

SEMINAR - II

II Year - IV Semester	L	P	C
	0	0	18

PROJECT WORK PART - II