M. Tech. Programme

in

POWER ELECTRONICS

SYLLABUS
FOR
CREDIT BASED UNIFORM CURRICULUM
(Applicable for 2015 batch onwards)

Department of Electrical and Electronics Engineering
National Institute of Technology
TIRUCHIRAPPALLI – 620015
TAMILNADU
INDIA

Revised Curriculum for M. Tech. Power Electronics

SEMESTER I

Code	Course of study	L	T	P	C
EE651	Power Converters	3	0	0	3
EE653	Industrial Control Electronics	3	0	0	3
EE655	Linear and Non-Linear Systems Theory	3	0	0	3
	Elective I	3	0	0	3
	Elective II	3	0	0	3
	Elective III	3	0	0	3
EE657	Power Converters Laboratory	0	0	3	2

SEMESTER II

Code	Course of study	L	T	P	C
EE652	Switched Mode Power Conversion	3	0	0	3
EE654	Power Electronic Drives	3	0	0	3
EE656	Microcontroller Applications in Power Converters	3	0	0	3
	Elective IV	3	0	0	3
	Elective V	3	0	0	3
	Elective VI	3	0	0	3

SEMESTER III

Code	Course of study	L	T	P	C
EE 697	Project Work (Phase I)	0	0	24	12

SEMESTER IV

Code	Course of study	L	T	P	C
EE 698	Project Work (Phase II)	0	0	24	12

ELECTIVES

Code	Course of study	L	T	P	C
MA603	Optimization Techniques	3	0	0	3
EE601	Advanced Power System Analysis	3	0	0	3
EE602	Power System Operation and Control	3	0	0	3
EE604	High Voltage DC Transmission	3	0	0	3
EE606	Flexible AC Transmission Systems	3	0	0	3
EE612	Advanced Digital Signal Processing	3	0	0	3
EE613	Advanced Digital System Design	3	0	0	3
EE614	Analysis and Design of Artificial Neural Networks	3	0	0	3
EE615	Digital Controllers in Power Electronics Applications	3	0	0	3
EE616	Computer Networking	3	0	0	3
EE617	Electrical Distribution Systems	3	0	0	3
EE618	Fuzzy Systems	3	0	0	3
EE619	Transient Over Voltages in Power Systems	3	0	0	3
EE621	Renewable Power Generation Technologies*	3	0	0	3
EE622	Power System Planning and Reliability	3	0	0	3
EE623	Advanced Power System Protection	3	0	0	3
EE624	Modeling and Analysis of Electrical Machines	3	0	0	3
EE625	Power Quality	3	0	0	3
EE626	Power System Restructuring and Pricing	3	0	0	3
EE627	Computer Relaying and Wide Area Measurement Systems	3	0	0	3
EE629	Swarm Intelligent Techniques	3	0	0	3
EE630	Smart Grid Technologies	3	0	0	3
EE631	Electrical Systems in Wind Energy	3	0	0	3
EE632	Embedded Processors and Controllers	3	0	0	3
EE633	Distributed Generation and Micro-Grids*	3	0	0	3
EE634	Control Design Techniques for Power Electronic Systems	3	0	0	3
EE635	Energy Auditing and Management	3	0	0	3
EE636	Electric and Hybrid Vehicles	3	0	0	3

EE637	Principles of VLSI Design	3	0	0	3
EE638	Advanced Topics in Power Electronics	3	0	0	3
EE639	Design Techniques for SMPS	3	0	0	3
EE640	Energy Storage Systems	3	0	0	3
EE641	Digital Simulation of Power Electronic Systems	3	0	0	3
EE642	PWM Converters and Applications	3	0	0	3
EE643	Embedded System Design	3	0	0	3
EE644	Digital Control Systems	3	0	0	3

**Will be offered as an Essential Elective for the benefit of M.Tech. (Power Electronics) students*

EE 651 POWER CONVERTERS

L	T	P	C
3	0	0	3

Course Objectives: To give a systematic approach for transient and steady state analysis of all power electronic converters with passive and active loads.

Prerequisites: Power Electronics in UG.

Analysis of power semiconductor switched circuits with R, L, RL, RC loads, d.c. motor load, battery charging circuit.

Single-Phase and Three-Phase AC to DC converters - Half controlled configurations - Operating domains of three phase full converters and semi-converters – Reactive power considerations.

Analysis and design of DC to DC converters – Control of DC-DC converters, Buck converters, Boost converters, Buck-Boost converters, Cuk converters.

Single phase and Three phase inverters, Voltage source and Current source inverters - Voltage control and harmonic minimization in inverters.

AC to AC power conversion using voltage regulators, choppers and cyclo-converters - Consideration of harmonics - Introduction to Matrix converters.

Reference Books:

1. Ned Mohan, Undeland and Robbin, 'Power Electronics: converters, Application and design', John Wiley and sons. Inc, Newyork, 2006.

2. RashidM.H.,'PowerElectronics-Circuits,DevicesandApplications',PrenticeHall India, NewDelhi, 2009.

3. P.CSen., 'Modern Power Electronics', Wheeler publishing Company, 1st Edition, New Delhi, 2005.

Course Outcomes:

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

1. Study and analyze transient response of basic power electronic circuits.
2. Understand the working of commonly used power converters.
3. Analyze and design various power converter systems.

EE653 INDUSTRIAL CONTROL ELECTRONICS

L	T	P	C
3	0	0	3

Course Objectives: This course gives a comprehensive coverage of various control electronics used in the industries. This combines the analog and digital concepts together with Power Electronics for the design of the controllers. Further an overview of stepper motor and servomotor with associated control circuits is given.

Prerequisites: Fundamental knowledge about analog, digital and Power electronic circuits.

Review of switching regulators and switch mode power supplies, Uninterrupted power supplies - off-line and on-line topologies - Analysis of UPS topologies, solid state circuit breakers, solid-state tap-changing of transformer.

Analog Controllers - Proportional controllers, Proportional – Integral controllers, PID controllers, derivative overrun, integral windup, cascaded control, Feed forward control, Digital control schemes, control algorithms, programmable logic controllers - Sensors for high voltage and current applications.

Signal conditioners - Instrumentation amplifiers – Voltage to current, current to voltage, voltage to frequency, frequency to voltage converters; Isolation circuits – cabling - magnetic and electro static shielding and grounding.

Opto-Electronic devices and control , electronic circuits for photo-electric switches - Output signals for photo-electric controls; Applications of opto-isolation, interrupter modules and photo sensors - Fibre-optics - Bar code equipment, application of barcode in industry.

Stepper motors – Types, operation, control and applications; Servo motors- Types, operation, control and applications – Servo motor controllers – Servo amplifiers – Linear motor applications - Selection of servo motor.

Reference Books:

1. *Michael Jacob, 'Industrial Control Electronics – Applications and Design', Prentice Hall, 1995.*
2. *Thomas E. Kissell, 'Industrial Electronics', Prentice Hall India, 2003.*
3. *James Maas, 'Industrial Electronics', Prentice Hall, 1995.*

Course Outcomes:

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

1. Understand the working of various power electronic circuits and components used in industrial applications.
2. Analyze various analog controllers and signal conditioning circuits.
3. Design control circuits for UPS and other industrial applications.

EE655 LINEAR AND NON-LINEAR SYSTEMS THEORY

L	T	P	C
3	0	0	3

Course Objectives: The main objective of this course is to understand the fundamental of physical systems in terms of its linear and nonlinear models. Exploit the properties of linear systems such as controllability and observability.

Prerequisites: Basic control, Linear algebra.

Introduction to state space modeling, modeling of physical systems - Solution to vector differential equations and state transition matrix.

Stability analysis of linear systems - Controllability and Observability definitions and Kalman rank conditions - Detectability and Stabilizability, Kalman decomposition.

State feedback controller design using pole placement - Observer design using Kalman filter algorithm - LQR and LQG controller design.

Introduction to nonlinear systems - Phase plane analysis of nonlinear system using linear approximation - Limit cycle and periodic solutions - Singular points (equilibrium points) and qualitative behavior near singular points.

Stability of nonlinear systems - Lyapunov direct and indirect methods - Input-to-state stability and relative stability.

Reference Books:

1. *Ogata, K., 'Modern Control Engineering', Prentice Hall of India, 2010.*
2. *C.T. Chen, 'Linear Systems Theory and Design'' Oxford University Press, 3rd Edition, 1999.*
3. *M. Vidyasagar, 'Nonlinear Systems Analysis', 2nd edition, Prentice Hall, Englewood Cliffs, New Jersey 07632.*
4. *Hassan K. Khalil, 'Nonlinear Systems', Pearson Educational International Inc. Upper Saddle River, 3rd Edition, 2001.*

Course Outcomes:

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

1. Understand and model physical systems using state vectors.
2. Analyze the stability of linear systems.
3. Design state feedback controllers and observers.
4. Understand and analyze non-linear systems using linear approximations.
5. Inspect the stability of non-linear systems by direct and indirect methods.

EE657 POWER CONVERTERS LABORATORY

L	T	P	C
0	0	3	2

Course Objectives: To enable the students to develop hands on experience in analyzing, designing and carrying out experiments on various power converters. It aims to familiarize the switching devices, power converters and its applications in various systems for power control.

Prerequisites: Power Electronics Laboratory at UG level.

List of Experiments

1. Simulation of following Power electronics Circuits
   - (a) Single-phase, three-phase semi converters and full converters
   - (b) DC-DC Choppers using SCRs and Self commutating devices
   - (c) Single-phase and three-phase inverters using IGBTs
   - (d) AC-AC voltage regulators
   - (e) DC and AC drives
2. Design and development of all above Power electronics circuits listed from (a) to (e).

Course Outcomes:

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

1. Analyze and design various power electronic converters.
2. Investigate the performance of DC and AC choppers.
3. Devise various control techniques for DC and AC drives.
4. Develop practical control circuits for various real time applications using different switching devices.

EE652 SWITCHED MODE POWER CONVERSION

L	T	P	C
3	0	0	3

Course Objectives: To understand the concepts, basic operation, steady state operation of efficient switched-mode power conversion techniques, including basic circuit operation and magnetic design.

Prerequisites: Power Converters.

Design constraints of reactive elements in Power Electronic Systems: Design of inductor, Transformer and capacitors for power electronic applications, Input filter design.

Basic concepts and steady state analysis of second and higher order Switched Mode power converters: PWM DC - DC Converters (CCM and DCM) - Operating principles, constituent elements, characteristics, comparisons and selection criteria.

Dynamic modeling and control of second and higher order switched mode power converters: Analysis of converter transfer functions, design of feedback compensators, current programmed, frequency programmed and critical conduction mode control.

Soft-switching DC - DC converters: Zero-voltage-switching converters, zero-current - Switching converters, multi-resonant converters and load resonant converters.

Pulse Width Modulated Rectifiers: Properties of ideal rectifier, realization of near ideal rectifier, control of the current waveform, single phase and three phase converter systems incorporating ideal rectifiers and design examples - Non-linear phenomena in switched mode power converters: Bifurcation and Chaos.

Reference Books:

1. *Robert W. Erickson and Dragan Maksimovic, 'Fundamentals of Power Electronics', Springer, 2nd Edition, 2001.*
2. *Marian K. Kazimierczuk, 'Pulse-width Modulated DC-DC Power Converters',John Wiley & Sons Ltd., 1st Edition, 2008.*
3. *Philip T Krein, 'Elements of Power Electronics', Oxford University Press, 2nd Edition, 2012.*
4. *Batarseh, 'Power Electronic Circuits', John Wiley, 2nd Edition, 2004.*
5. *H. W. Whittington, B. W. Flynn, D. E. Macpherson, 'Switched Mode Power Supplies', John Wiley & Sons Inc., 2nd Edition, 1997.*

Course Outcomes:

Upon completion of the course, the students will be able to recognize and use the following concepts, ideas, and/or tools:

1. Steady-State Analysis of switched-mode dc-dc power converters.
2. Design of Switched-Mode Converters, including selection of component values based on steady-state dc and ac ripple specifications.
3. Dynamic Modelling Development and Analysis for switched-mode dc-dc converters using averaging techniques, including the derivation and visualization of converter small-signal transfer functions.
4. Analysis and Design of Control Loops around switched-mode power converters using averaging small-signal dynamic models and classical control theory.
5. Become proficient with computer skills (e.g., PSPICE and MATLAB) for the analysis and design of switched-mode power converters.

EE654 POWER ELECTRONIC DRIVES

L	T	P	C
3	0	0	3

Course Objectives: To introduce basic concepts of load and drive interaction, speed control concepts of ac and dc drives, speed reversal, regenerative braking aspects, design methodology.

Prerequisites: A course in Power Electronics and electrical machines.

Basic power electronic drive system, components - Different types of loads, shaft-load coupling systems - Stability of power electronic drive.

Conventional methods of D.C. motor speed control - single phase and three phase converter fed D.C motor drive - Power factor improvement techniques, four quadrant operation.

Chopper fed drives, input filter design - Braking and speed reversal of DC motor drives using choppers, multiphase choppers - PV fed DC drives.

Conventional methods of induction motor speed control - Solid state controllers for stator voltage control, soft starting of induction motors, rotor side speed control of wound rotor induction motors - Voltage source and Current source inverter fed induction motor drives – d-q axis modeling and vector control.

Speed control of synchronous motors, field oriented control, load commutated inverter drives, switched reluctance motors and permanent magnet motor drives - Introduction to design aspects of machines.

Reference Books:

1. *P.C Sen, ‘Thyristor DC Drives’, John Wiley and Sons, New York, 1991.*
2. *R. Krishnan, ‘Electric Motor Drives – Modeling, Analysis and Control’, Prentice-Hall of India Pvt. Ltd., New Delhi, 2003.*
3. *Bimal K .Bose, ‘Modern Power Electronics and AC Drives’, Pearson Education (Singapore) Pvt. Ltd., New Delhi, 2003.*

Course Outcomes:

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

1. Understand and analyze dc and ac motors supplied from different power converters.
2. Simulate and study motor characteristics with different converter configurations.
3. Design and implement a prototype drive system.

EE656 MICROCONTROLLER APPLICATIONS IN POWER CONVERTERS

L	T	P	C
3	0	0	3

Course Objectives: Study the internal structure and operation of PIC 16F876 microcontroller and 8051 microcontroller; assembly language program for the generation of firing and control signals employing these microcontrollers.

Prerequisites: Knowledge on any digital controller and power electronics may be desirable.

8051 microcontroller – Architecture – Addressing modes – I/O ports - Instruction sets – Simple assembly language programming.

Use of microcontrollers for pulse generation in power converters - Overview of Zero-Crossing Detectors – typical firing/gate-drive circuits – Firing/gate pulses for typical single phase and three phase power converters - PIC16F876 Micro-controller – Device overview – Pin diagrams.

PIC16F876 micro-controller memory organization – Special Function Registers - I/O ports – Timers – Capture/ Compare/ PWM modules (CCP).

Analog to Digital Converter module – Instruction set – Instruction description – Introduction to PIC microcontroller programming – Oscillator selection – Reset – Interrupts – Watch dog timer.

Introduction to MPLAB IDE and PICSTART plus – Device Programming using MPLAB and PICSTART plus – Generation of firing / gating pulses for typical power converters.

Reference Books:

1. *PIC16F87X Datasheet 28/40–pin 8 bit CMOS flash Microcontrollers, Microchip technology Inc., 2001. and MPLAB IDE Quick start guide, Microchip technology Inc., 2007.*
2. *John B. Peatman, ‘Design with PIC Microcontrollers’, Prentice Hall, 2003.*
3. *MykePredko, ‘Programming and customizing the PIC Microcontroller’, Tata McGraw-Hill, 3rd Edition, 2008.*
4. *M.A. Mazidi, J.G. Mazidi and R.D. McKinlay, ‘The 8051 microcontroller and embedded systems’, Prentice Hall India, 2nd Edition, New Delhi, 2007.*

Course Outcomes:

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

1. Understand the architecture of 8051 and 16F876 microcontrollers.
2. Develop assembly language programs employing 8051 & 16F876 microcontrollers.
3. Analyze the microcontroller programming using MPLAB and develop typical programs for power converter applications.

MA603 OPTIMIZATION TECHNIQUES

L	T	P	C
3	0	0	3

Course Objectives: To learn essential optimization techniques for applying to day to day problems.

Prerequisites: Undergraduate level mathematics.

Linear programming – Formulation - Graphical and simplex methods - Big-M method - Two phase method - Dual simplex method - Primal Dual problems.

Unconstrained one dimensional optimization techniques - Necessary and sufficient conditions – Unrestricted search methods - Fibonacci and Golden section method - Quadratic Interpolation methods, cubic interpolation and direct root methods.

Unconstrained n dimensional optimization techniques – Direct search methods – Random search – Pattern search and Rosen brock's hill climbing method - Descent methods - Steepest descent, conjugate gradient, quasi - Newton method.

Constrained optimization Techniques - Necessary and sufficient conditions – Equality and inequality constraints - Kuhn-Tucker conditions - Gradient projection method - Cutting plane method - Penalty function method.

Dynamic programming - Principle of optimality - Recursive equation approach - Application to shortest route, cargo - loading, allocation and production schedule problems.

Reference Books:

1. Rao, *S.S., 'Optimization :Theory and Application', Wiley Eastern Press, 2nd edition 1984.*
2. *Taha, H.A.,'Operations Research –An Introduction', Prentice Hall of India,2003.*
3. *Fox, R.L., 'Optimization methods for Engineering Design', Addison Wesley, 1981.*

Course Outcomes:

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

1. Understand formulation of linear programming based problems and apply graphical and simplex methods.
2. Apply appropriate optimization technique and analyze unconstrained one dimensional problems.
3. Apply appropriate optimization technique and analyze unconstrained multi-dimensional problems.
4. Appraise and evaluate constrained optimization problems related to Power Systems by appropriate methods.

EE 601 ADVANCED POWER SYSTEM ANALYSIS

L	T	P	C
3	0	0	3

Course Objectives: To perform steady state analysis and fault studies for a power system of any size and also to explore the nuances of estimation of different states of a power system.

Prerequisites: A basic knowledge on the subjects viz., Power System analysis, Matrix manipulations, Alternating machines and network analysis.

Network modeling – Single phase and three phase modeling of alternators, transformers and transmission lines, Conditioning of Y Matrix –- Incidence matrix method, Method of successive elimination, Triangular factorization – Sparse matrix.

Load flow analysis - Newton Raphson method, Fast Decoupled method, AC-DC load flow –Single and three phase methods – Sequential solution techniques and extension to multiple and multi-terminal DC systems.

Fault Studies - Analysis of balanced and unbalanced three phase faults – Fault calculations – Short circuit faults – Open circuit faults.

System optimization - Strategy for two generator systems – Generalized strategies – Effect of transmission losses - Sensitivity of the objective function - Formulation of optimal power flow-solution by Gradient method-Newton's method.

State Estimation – Method of least squares – Statistics – Errors – Estimates – Test for bad data – Structure and formation of Hessian matrix – Power system state estimation.

Reference Books:

1. *Grainger, J.J. and Stevenson, W.D., 'Power System Analysis', Tata McGraw Hill, New Delhi, 2003.*
2. *HadiSaadat, 'Power System Analysis', Tata McGraw Hill, New Delhi, 2002.*
3. *Arrillaga, J and Arnold, C.P., 'Computer Analysis of Power Systems', John Wiley and Sons, New York, 1997.*
4. *Pai, M.A., 'Computer Techniques in Power System Analysis', Tata McGraw Hill, New Delhi, 2006.*

Course Outcomes:

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

1. Construct models of power system components and apply them.
2. Solve ac and dc load flow for single and there phase systems.
3. Analyse the faults in the power system networks.
4. Apply the concepts of optimization in power system.
5. Explain the concept of state estimation in power system and the role of statistics in state estimation.

EE602 POWER SYSTEM OPERATION AND CONTROL

L	T	P	C
3	0	0	3

Course Objectives:

- To understand the economics of power system operation with thermal and hydro units.
- To realize the requirements and methods of real and reactive power control in power system.
- To be familiar with the power system security issues and contingency studies.

Prerequisites: Optimization Techniques, Advanced Power System Analysis.

Economic operation - Load forecasting - Unit commitment – Economic dispatch problem of thermal units – Gradient method- Newton's method – Base point and participation factor method.

Hydro-thermal co-ordination - Hydroelectric plant models – Short term hydrothermal scheduling problem - Gradient approach – Hydro units in series - pumped storage hydro plants - Hydro-scheduling using Dynamic programming and linear programming.

Automatic generation control - Review of LFC and Economic Dispatch control (EDC) using the three modes of control viz. Flat frequency – Tie-line control and tie-line bias control – AGC implementation – AGC features - Static and dynamic response of controlled two area system.

MVAR control - Application of voltage regulator – Synchronous condenser – Transformer taps – Static VAR compensators.

Power system security - Contingency analysis – Linear sensitivity factors – AC power flow methods – contingency selection – Concentric relaxation – Bounding-security constrained optimal power flow - Interior point algorithm - Bus incremental costs.

Reference Books:

1. *Robert H. Miller, James H. Malinowski, 'Power system operation', Tata McGraw-Hill, 2009.*
2. *Allen J. Wood, Bruce F. Wollenberg, 'Power Generation,Operation and Control', Wiley India Edition, 2nd Edition, 2009.*
3. *Abhijit Chakrabarti & Sunita Halder, 'Power System Analysis-Operation & Control', PHI, 3rd Edition, 2010.*
4. *T J Miller, 'Reactive Power Control in Electric Systems', Wiley, 1982.*

Course Outcomes:

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

1. Develop generation dispatching schemes for thermal and hydro units.
2. Apply control and compensations schemes on a power system.
3. Adopt contingency analysis and selection methods to improve system security.

EE604 HIGH VOLTAGE DC TRANSMISSION

L	T	P	C
3	0	0	3

Course Objectives: To facilitate the students understand the basic concepts and recent trends in HVDC transmission system and its applications.

Prerequisites: Basic knowledge in circuit analysis, Control Systems power system and Power Electronic devices and circuits.

Introduction to HVDC transmission, Comparison between HVAC and HVDC systems - Economic, technical and reliability, limitations, Types of HVDC links - monopolar, bipolar and homopolar links, Components of HVDC transmission system.

Analysis of HVDC Converters, Rectifier and Inverter operation of Graetz circuit without and with overlap. Output voltage waveforms and DC voltage in both rectifier and inverter operation, Equivalent circuit of HVDC link.

Basic means of HVDC system control, desired features, power reversal, Basic controllers - constant ignition angle, constant current and constant extinction/ advance angle control, power control, high level controllers. Converter maloperations - misfire, arc through, commutation failure.

Harmonics in HVDC system - Characteristic and uncharacteristic harmonics - Troubles due to harmonics – Harmonic filters - Active and passive filters - Reactive power control of converters, Protection issues in HVDC, over voltage and over current protection - Voltage and current oscillations, DC reactor design, DC Circuit breakers.

Recent trends in HVDC transmission - CSC based HVDC system, VSC based HVDC system – Multi-terminal HVDC systems and HVDC system applications in wind power generation, Interaction between AC and DC systems

Reference Books:

1. *Kimbark, E.W., 'Direct Current Transmission-vol.1', Wiley Inter science, New York, 1971.*
2. *Padiyar, K.R., 'HVDC transmission systems', Wiley Eastern Ltd., 2010.*
3. *Kamakshaiah, S and Kamaraju, V, 'HVDC Transmission', 1st Edition, Tata McGraw Hill Education (India), Newdelhi 2011.*
4. *Arrilaga, J., 'High Voltage Direct Current Transmission', 2nd Edition, Institution of Engineering and Technology, London, 1998.*
5. *Vijay K. Sood, 'HVDC and FACTS Controllers', Kluwer Academic Publishers, New York, 2004.*

Course Outcomes:

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

1. Appraise the need of HVDC technology for bulk power transmission and choose appropriate type of HVDC link and converter.
2. Analyze the operation of Graetz circuit as rectifier and inverter without and with overlap.
3. Evaluate the operation and efficacy of different controllers and analyze the different faults in HVDC systems.
4. Discriminate and evaluate the issues related with harmonics, reactive power control and protection of HVDC system.
5. Recognize and appraise the recent trends in HVDC transmission systems.

EE606 FLEXIBLE AC TRANSMISSION SYSTEMS

L	T	P	C
3	0	0	3

Course Objectives: To familiarize students with the transmission challenges of modern electrical power systems. The course will present the basic concepts, principles and operation of fast high power electronic controllers known as Flexible AC Transmission Systems (FACTS) that enhance power system stability and effectively increase transmission capacity thus yielding significantly higher flexibility of operation. The course will focus on concepts and applications various configurations of FACTs controllers. Both thyristor based and also voltage source converters based FACTS Controllers are discussed.

Prerequisites: Power System Analysis, Power Conversion techniques or equivalent.

Fundamentals of ac power transmission - Transmission problems and needs - Emergence of FACTS - FACTS control considerations - FACTS controllers.

Principles of shunt compensation – Variable Impedance type & switching converter type - Static Synchronous Compensator (STATCOM) configuration - Characteristics and control.

Principles of static series compensation using GCSC, TCSC and TSSC – Applications - Static Synchronous Series Compensator (SSSC).

Principles of operation - Steady state model and characteristics of a static voltage regulators and phase shifters - Power circuit configurations.

UPFC - Principles of operation and characteristics - Independent active and reactive power flow control - Comparison of UPFC with the controlled series compensators and phase shifters.

Reference Books:

1. *Song, Y.H. and Allan T. Johns, 'Flexible AC Transmission Systems (FACTS)', Institution of Electrical Engineers Press, London, 1999.*
2. *Hingorani ,L.Gyugyi, 'Concepts and Technology of Flexible AC Transmission System', IEEE Press New York, 2000 ISBN –078033 4588.*
3. *Mohan Mathur R. and Rajiv K.Varma, 'Thyristor - based FACTS controllers for Electrical transmission systems', IEEE press, Wiley Inter science , 2002.*
4. *Padiyar K.R., 'FACTS controllers for Transmission and Distribution systems', New Age International Publishers, 1st Edition, 2007.*
5. *Enrique Acha, Claudio R.Fuerte-Esqivel, Hugo Ambriz-Perez, Cesar Angeles-Camacho, 'FACTS – Modeling and simulation in Power Networks', John Wiley & Sons, 2002.*

Course Outcomes:

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

1. Identify the conditions in conventional power system where the installation of FACTS controllers or Devices becomes vital.
2. Analyze the performance of a conventional transmission system and apply the principles of reactive power compensation for improvement.
3. Illustrate the modes of operation of thyristor based and voltage source converter based FACTS controllers and explain the capabilities and modeling aspects.
4. Analyze different series, shunt or combined series-shunt FACTS controllers and compute the performance when installed in a given transmission system.
5. Compare the characteristics of different FACTS controllers and defend the choice of a particular controller to suit the given system/ scenario.

EE612 ADVANCED DIGITAL SIGNAL PROCESSING

L	T	P	C
3	0	0	3

Course Objectives: Review and understanding of discrete-time systems and signals, Discrete-Time Fourier Transform and its properties, the Fast Fourier Transform, design of Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filters, implementation of digital filters.

Prerequisites: Signals and Systems, Circuit Theory.

Review of Discrete – Time Signal & System representation in Z-Transform domain – Inverse Z-Transform – Properties – System characterization in Z-domain - Equivalence between Fourier Transform and the Z - Transform of a Discrete signal.

Sampling in Fourier domain - Discrete Fourier Transform and its properties – Linear filtering using DFT – Resolution of DFT - FFT Algorithm – Radix-2 FFT Algorithm - DIT & DIF Structures - Higher Radix schemes.

Classification of filter design - Design of IIR filters – Bilinear transformation technique – Impulse invariance method – Step invariance method.

FIR filter design – Fourier series method - Window function technique - Finite Word Length Effects.

Introduction to Multirate Signal Processing - Decimation - Interpolation – Introduction to STFT WT.

Reference Books:

1. *John G. Prokis and Dimitris G. Hanolakis, 'Digital Signal Processing, Principles, Algorithms & Applications', Pearson Education, 4^{th} Edition, 2006.*
2. *Ludemann L. C., 'Fundamentals of Digital Signal Processing', Harper and Row publications, 2009.*
3. *Antoniou A., 'Digital Filters – Analysis and Design', Tata Mc-Graw Hill, 2001.*
4. *Oppenheim and Schaffer, 'Discrete time Signal processing', Pearson Education, 2007.*

Course Outcomes:

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

1. Understand the basic of discrete-time signals, systems and Z-Transform.
2. Perform discrete-time Fourier Transform and digital Fourier Transform.
3. Design different kinds of digital filters.

EE 613 ADVANCED DIGITAL SYSTEM DESIGN

L	T	P	C
3	0	0	3

Course Objectives: To impart the knowledge on the advanced topics of Digital systems, design aspects and testing of the circuits.

Prerequisites: Digital Electronics.

Review of sequential circuits - Mealy & Moore Models - Analysis & Synthesis of Synchronous sequential circuits.

Digital system design Hierachy - ASM charts - Hardware description language - Control logic Design Reduction of state tables - State Assignments.

Analysis and synthesis of Asynchronous sequential circuits - Critical and non-critical races - Essential Hazard.

Combinational and sequential circuit design with PLD's - Introduction to CPLD's & FPGA's.

Fault classes and models – Stuck at faults, Bridging faults - Transition and Intermittent faults - Fault Diagnosis of combination circuits by conventional methods - Path sensitization technique - Boolean different method and Kohavi algorithm.

Reference Books:

1. *Donald D. Givone, 'Digital principles and design', Tata McGraw-Hill, 2003.*
2. *Morris Mano, 'Digital Design', Prentice Hall India, 3rd Edition, 2007.*
3. *Samuel C. Lee, 'Digital circuits and logic design', Prentice Hall India, 1984.*
4. *N. N. Biswas, 'Logic Design Theory', Prentice Hall India, 1993.*
5. *ZviKohavi, 'Switching and Finite Automata Theory', Tata McGraw-Hill, 3rd Edition, 2010.*

Course Outcomes:

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

1. Understand the concepts of synchronous sequential circuits.
2. Formulate the state tables and ASM charts for digital system.
3. Design circuits using programmable logic devices.
4. Identify faults in the digital circuits.
5. Analyze and synthesize asynchronous sequential circuits.

EE614 ANALYSIS AND DESIGN OF ARTIFICIAL NEURAL NETWORKS

L	T	P	C
3	0	0	3

Course Objectives: To apply artificial neural networks in various electrical and electronics engineering applications.

Prerequisites: Introduction to Electrical and Electronics Engineering, Basic mathematics and Probability.

Pattern classification – Learning and generalization - Structure of neural networks – ADA line and Mada line - Perceptrons.

Linear separability – Back propagation – XOR function-Back propagation algorithm - Hopfied and Hamming networks- Kohensen's network - Boltzmenn machine-in and out star network – Art 1 and Art 2 nets.

Neuro adaptive control applications - ART architecture – Comparison layer – Recognition layer – ART classification process – ART implementation – Examples.

Character recognition networks - Neural network control application - connectionist expert systems for medical diagnosis - self-organizing maps.

Applications of neural algorithms and systems - Character recognition networks, Neural network control application, connectionist expert systems for medical diagnosis.

Reference Books:

1. *Martin T. Hagan, Howard B.Demuth, M, and Mark H. Beale ,'Neural network design', Vikas Publishing House, 2003.*
2. *Zurada, J.M., 'Introduction to Artificial Neural Systems', Jaico publishing house, Bombay, 1992.*
3. *Zimmermann, H.J., 'Fuzzy set theory and its applications', Allied publishers limited, Madras, 2001.*

Course Outcomes:

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

1. Explain the concepts of biological and artificial neural network.
2. Understand the different modes of operation in artificial neural network.
3. Discriminate the first generation and second generation neural networks.
4. Understand the third generation neural networks.
5. Apply neural network in pattern recognition, forecasting, control, clustering, data mining and decision making engineering problems.

EE615 DIGITAL CONTROLLERS IN POWER ELECTRONICS APPLICATIONS

L	T	P	C
3	0	0	3

Course Objectives: To enrich the learner with digital controller concepts and its application in the field of Power Electronic Systems.

Prerequisites: Digital Electronics, Digital Signal Processing, Computer Architecture.

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.

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.

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.

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.

Controlled Rectifier - Switched Mode Power Converters - PWM Inverters - DC motor control - Induction Motor Control.

Reference Books:

1. *Hamid.A.Toliyat and Steven G.Campbell, 'DSP Based Electro Mechanical Motion Control' ,CRC Press New York , 2004.*
2. *XC 3000 series datasheets (version 3.1). Xilinx, Inc., USA, 1998.*
3. *XC 4000 series datasheets (version 1.6). Xilinx, Inc., USA, 1999.*
4. *Wayne Wolf, 'FPGA based system design', Prentice hall, 2004.*

Course Outcomes:

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

1. Understand the architecture of DSP core and its functionalities.
2. Acquire knowledge on operation of interrupts and peripherals.
3. Explore the possibilities of hardware implementation using PLDs and FPGAs.
4. Design of controllers for power converters.

EE616 COMPUTER NETWORKING

L	T	P	C
3	0	0	3

Course Objectives: This course provides an introduction to the computer networking fundamentals, design issues, functions and protocols of the network architecture.

Prerequisites: Data Structures and Communication Systems.

Computer Network – Hardware and Software, OSI and TCP reference Model, Transmission media, Wireless transmission, public switched telephone network - Structure, multiplexing and switching.

Data link layer - Design issues, data link protocols. Medium access sub layer - Channel allocations, Multiple Access protocols, IEEE protocols.

Network layer - Design issues, routing algorithms, congestion control algorithms, QoS , Transport layer - Design issues, connection management .

Application layer – DNs, Electronic mail, World Wide Web, multimedia, Cryptography.

Internet transport protocols - TCP and UDP.

Reference Books:

1. *James F. Kurose and Keith W. Ross, 'Computer Networking', Pearson Education, 2nd Edition, 2003.*
2. *Tanenbaum, A.S., 'Computer Networks', Prentice Hall of India, 4th Edition, 2003.*
3. *Stallings W., 'Data and Computer Communication', Prentice Hall of India, 5th Edition, 2000.*

Course Outcomes:

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

1. Describe the different layers of the network architecture models and their functions.
2. Appraise the need of the various protocols across different layers.
3. Suggest a particular routing protocol and congestion technique for an application.

EE617 ELECTRICAL DISTRIBUTION SYSTEMS

L	T	P	C
3	0	0	3

Course Objectives:

- To explain the principles of design and operation of electric distribution feeders and other components.
- To make the students to understand the distribution system expansion planning and reliability analysis procedures.

Prerequisites: Transmission and Distribution of Electrical Energy, Power System Analysis.

Industrial and commercial distribution systems – Energy losses in distribution system – System ground for safety and protection – Comparison of O/H lines and underground cable system - Network model – Power flow - Short circuit and loss calculations.

Distribution system - Reliability analysis – Reliability concepts – Markov model – Distribution network reliability – Reliability performance.

Distribution system expansion - Planning – Load characteristics – Load forecasting – Design concepts – optimal location of substation – Design of radial lines – Solution technique.

Voltage control – Application of shunt capacitance for loss reduction – Harmonics in the system – Static VAR systems – Loss reduction and voltage improvement.

System protection – Requirement – Fuses and section analyzers - Over current - Under voltage and under frequency protection – Coordination of protective device.

Reference Books:

1. *Pabla, A.S., 'Electrical Power Distribution System', 5th edition, Tata McGraw Hill, 2011.*
2. *Tuvar Goner, 'Electrical Power Distribution System Engineering', McGraw Hill, 2008.*
3. *Sterling, M.J.H., 'Power System Control', Peter Peregrinus, 1986.*

Course Outcomes:

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

1. Do loss calculation in distribution lines.
2. Select the protective components for distribution systems.
3. Carry out planning and reliability analysis of electrical distribution systems.

EE618 FUZZY SYSTEMS

L	T	P	C
3	0	0	3

Course Objectives: This course is designed to expose students to fuzzy methods of analyzing problems which involve incomplete or vague criteria rather than crisp values. The course investigates requirements analysis, logical design, and technical design of components for fuzzy systems development.

Prerequisites: Control Systems

Different faces of imprecision – Inexactness, Ambiguity, Undecidability, Fuzziness and certainty, Probability and fuzzy logic, Intelligent systems.

Fuzzy sets and crisp sets - Intersections of Fuzzy sets, Union of Fuzzy sets, the complement of Fuzzy sets.

Fuzzy reasoning - Linguistic variables, Fuzzy propositions, Fuzzy compositional rules of inference- Methods of decompositions, Defuzzification.

Methodology of fuzzy design - Direct & Indirect methods with single and multiple experts, Adaptive fuzzy control, Rule base design using dynamic response.

Fuzzy logic applications to engineering, Fuzzy decision making, Neuro-Fuzzy systems, Fuzzy Genetic Algorithms.

Reference Books:

1. *Zimmermann H. J., 'Fuzzy set theory and its applications', Allied publishers limited, Madras, 4th Edition, 2001*
2. *Klir G. J. and Folger T., 'Fuzzy sets, uncertainty and information', Prentice Hall of India, New Delhi, 1991.*
3. *EarlCox, 'The Fuzzy Systems Handbook', AP professional Cambridge, 1999.*

Course Outcomes:

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

1. Assimilate the uncertainty concept.
2. Apply and analyze fuzzy sets for existing systems.
3. Develop fuzzy logic theory for linear and non-linear systems.

EE619 TRANSIENT OVER VOLTAGES IN POWER SYSTEMS

L	T	P	C
3	0	0	3

Course Objectives: To make the students familiar with the theoretical basis for various forms of over voltages such as lighting strokes, surges, switching transients etc., and to introduce some of the protection measures against such over voltages are described. Also to depict the necessity and methods for generating impulse voltages and currents.

Prerequisites: Advanced Power System Analysis.

Transients in electric power systems – Internal and external causes of over voltages -– Lightning strokes – Mathematical model to represent lightning, Travelling waves in transmission lines – Circuits with distributed constants – Wave equations – Reflection and refraction of travelling waves – Travelling waves at different line terminations.

Switching transients – Double frequency transients – Abnormal switching transients –Transients in switching a three phase reactor - Three phase capacitor.

Voltage distribution in transformer winding – Voltage surges - Transformers – Generators and motors Transient parameter values for transformers, reactors, generators and transmission lines.

Basic ideas about protection – Surge diverters - Surge absorbers - Protection of lines and stations - Modern lighting arrestors - Insulation coordination - Protection of alternators and industrial drive systems.

Generation of high AC and DC - Impulse voltages, currents - Measurement using sphere gaps - Peak voltmeters - Potential dividers and CRO.

Reference Books:

1. *Allen Greenwood, 'Electrical transients in power systems', Wiley Interscience, 1991.*
2. *Bewley, L.V., 'Travelling waves on Transmission systems', Dover publications, New York, 1963.*
3. *Gallaghar, P.J. and Pearman, A.J., 'High voltage measurement, Testing and Design', John Wiley and sons, New York, 2001.*

Course Outcomes:

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

1. Recognize and construct different circuits representing lightning and travelling waves.
2. Analyze various switching transients in power systems.
3. Appraise voltage surges in different electrical machines.
4. Understand basic protection of machines, stations and lines.
5. Appreciate methods of generating and measuring A.C. and D.C., impulse voltages.

EE621 RENEWABLE POWER GENERATION TECHNOLOGIES

L	T	P	C
3	0	0	3

Course Objectives: This course makes the student to

- Aware of various forms of renewable energy.
- Understand in detail the wind energy conversion system and photovoltaic conversion system.

Prerequisites: Basic Electronics and Machines, Power Electronics.

Sun and Earth - Basic Characteristics of solar radiation - Angle of sunrays on solar collector - Photovoltaic cell - characteristics-equivalent circuit - Photovoltaic modules and arrays.

PV Systems-Design of PV systems - Standalone system with DC and AC loads with and without battery storage - Grid connected PV systems - Maximum Power Point Tracking.

Wind energy – Energy in the wind – Aerodynamics - Rotor types – Forces developed by blades - Aerodynamic models – Braking systems – Tower - Control and monitoring system - Design considerations - Power curve - Power speed characteristics - Choice of electrical generators.

Wind turbine generator systems - Fixed speed induction generator - Performance analysis - Semi variable speed induction generator - Variable speed induction generators with full and partial rated power converter topologies - Isolated systems - Self excited induction generator - Permanent magnet alternator - Performance analysis.

Hybrid energy systems - Wind-diesel system - Wind-PV system - Micro hydro-PV system - Biomass-PV-diesel system - Geothermal-tidal and OTEC systems.

Reference Books:

1. *Chetan Singh Solanki, 'Solar Photovoltaics -Fundamentals, Technologies and Applications', PHI Learning Pvt. Ltd., New Delhi, 2011.*
2. *Van Overstraeton and Mertens R.P., 'Physics, Technology and use of Photovoltaics', Adam Hilger, Bristol,1996.*
3. *John F.Walker& Jenkins. N , 'Wind energy Technology', John Wiley and sons, Chichester, UK, 1997.*
4. *Freries LL ,'Wind Energy Conversion Systems', Prentice Hall, U.K., 1990.*

Course Outcomes:

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

1. Appraise the need and possibility of extracting solar energy and converting into electrical energy using PV cell.
2. Design and analyze stand-alone and grid connected PV system.
3. Describe the dynamics of wind turbine and electrical generator.
4. Select and design suitable configuration of the wind energy conversion system based on application.
5. Suggest, design and analyze hybrid energy systems.

EE622 POWER SYSTEM PLANNING AND RELIABILITY

L	T	P	C
3	0	0	3

Course Objectives: To acquire skills in planning and building reliable power system.

Prerequisites: Power system analysis, Power system transmission and distribution, Matrices, Probability and Calculus.

Objectives of planning – Long and short term planning - Load forecasting – Characteristics of loads – methodology of forecasting – Energy forecasting – Peak demand forecasting – Total forecasting – Annual and monthly peak demand forecasting.

Reliability concepts – Exponential distributions – Meantime to failure – Series and parallel system – MARKOV process – Recursive technique - Generator system reliability analysis – Probability models for generators unit and loads – Reliability analysis of isolated and interconnected system – Generator system cost analysis – Corporate model – Energy transfer and off peak loading.

Transmission system reliability model analysis – Average interruption rate - LOLP method - Frequency and duration method.

Two plant single load system - Two plant two load system - Load forecasting uncertainly interconnections benefits.

Introduction to system modes of failure – The loss of load approach – Frequency & duration approach – Spare value assessment – Multiple bridge equivalents.

Reference Books:

1. *Sullivan, R.L., 'Power System Planning', Heber Hill, 1987.*
2. *Roy Billington, 'Power System Reliability Evaluation', Gordan& Breach Scain Publishers, 1990.*
3. *Eodrenyi, J., 'Reliability modeling in Electric Power System', John Wiley, 1980.*

Course Outcomes:

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

1. Explain the characteristics of loads, concepts of load forecasting and its types for power system planning.
2. Comprehend the significance of reliability in power system, various methods and tools used for reliability analysis.
3. Describe the concepts of reliability in generation and transmission system and system interconnection.
4. Discriminate the different modes of system failure and to explain various approaches to assess power system failure.

EE623 ADVANCED POWER SYSTEM PROTECTION

L	T	P	C
3	0	0	3

Course Objectives:

- To facilitate the students understand the basic concepts and recent trends in power system protection.
- To enable the students design and work with the concepts of digital and numerical relaying.

Prerequisites: Basic knowledge on short circuit analysis, digital system and signal processing.

General philosophy of protection - Classification and Characteristic function of various protective relays-basic relay elements and relay terminology - Development of relaying scheme.

Digital Protection of power system apparatus – Protection of generators – Transformer protection – magnetizing inrush current – Application and connection of transformer differential relays – Transformer over current protection.

Bus bar protection - Line protection - Distance protection – Long EHV line protection - Power line carrier protection.

Reactor protection – Protection of boosters - Capacitors in an interconnected power system.

Digital signal processing – Digital filtering in protection relays - Numeric protection – Testing Digital filtering in protection relays – Digital data transmission – Relay hardware – Relay algorithms - Concepts of modern coordinated control system.

Reference Books:

1. *Lewis Blackburn, J., ‘Protective Relaying – Principles and Applications’, Marcel Dekkar, INC, New York, 2006.*
2. *The Electricity Training Association, ‘Power System Protection Vol1-4’, The IEE, U.K., 2005.*
3. *C. Russeil Mason, ‘The art and Science of Protective Relaying’, GE Publishers, 1962.*
4. *T. Johns and S. K. Salman, ‘Digital Protection for Power Systems’, Peter Peregrinus Ltd.,1997.*
5. *Arun G Padkye and James S Thorp, ‘Computer Relaying for Power Systems’, John Wiley publications, 2nd Edition, 2009.*
6. *P M Anderson, ‘Power System Protection’, IEEE Press, 2012.*

Course Outcomes:

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

1. Describe the characteristics of various relays.
2. Develop analog and digital circuit based protection for alternator, transformer.
3. Describe various schemes of protection for busbar, transmission line, capacitor and boosters.
4. Illustrate the implementation flow of a numerical flow.

EE624 MODELING AND ANALYSIS OF ELECTRICAL MACHINES

L	T	P	C
3	0	0	3

Course Objectives: To give a systematic approach for modeling and analysis of all rotating machines under both transient and steady state conditions.

Prerequisites: Electromagnetic field theory, vector algebra and fundamentals of all electrical rotating machines.

Principles of Electromagnetic Energy Conversion, General expression of stored magnetic energy, co-energy and force/torque, example using single and doubly excited system.

Basic Concepts of Rotating Machines - Calculation of air gap mmf and per phase machine inductance using physical machine data - Voltage and torque equation of dc machine.

Three phase symmetrical induction machine and salient pole synchronous machines in phase variable form - Application of reference frame theory to three phase symmetrical induction and synchronous machines, dynamic direct and quadrature axis model in arbitrarily rotating reference frames.

Determination of Synchronous Machine Dynamic Equivalent Circuit Parameters, Analysis and dynamic modeling of two phase asymmetrical induction machine and single phase induction machine.

Special Machines - Permanent magnet synchronous machine: Surface permanent magnet (square and sinusoidal back emf type) and interior permanent magnet machines - Construction and operating principle, dynamic modeling and self controlled operation - Analysis of Switch Reluctance Motors.

Reference Books:

1. *Charles Kingsley,Jr., A.E. Fitzgerald, Stephen D.Umans, 'Electric Machinery', Tata Mcgraw Hill, 5th Edition, 1992.*
2. *R. Krishnan, 'Electric Motor & Drives: Modeling, Analysis and Control', Prentice Hall of India, 2nd Edition, 2001.*
3. *Miller, T.J.E., 'Brushless Permanent Magnet and Reluctance Motor Drives', Clarendon Press, 1st Edition, 1989.*

Course Outcomes:

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

1. Understand principles of energy conversion.
2. Analyze basic concepts of rotating machines.
3. Construct machine models based on different reference frames.
4. Analyze and synthesize equivalent circuit parameters for synchronous and asynchronous machines.
5. Understand and analyze special machines.

EE625 POWER QUALITY

L	T	P	C
3	0	0	3

Course Objectives:

- To understand the various power quality phenomenon, their origin and monitoring and mitigation methods.
- To understand the effects of various power quality phenomenon in various equipment.

Prerequisites : Power Systems, Signals and Systems.

Electric power quality phenomena - IEC and IEEE definitions - Power quality disturbances - Voltage fluctuations – Transients – Unbalance - Waveform distortion - Power frequency variations.

Voltage variations - Voltage sags and short interruptions – Flicker-longer duration variations - Sources – Range and impact on sensitive circuits - Standards – Solutions and mitigations – Equipment and techniques.

Transients – Origin and classifications – Capacitor switching transient – Lightning - load switching – impact on users – Protection – Mitigation.

Harmonics – Sources – Definitions & standards – Impacts - Calculation and simulation – Harmonic power flow - Mitigation and control techniques – Filtering – Passive and active.

Power quality conditioners – Shunt and series compensators - DStatcom - Dynamic voltage restorer - Unified power quality conditioners - Case studies.

Reference Books:

1. *Heydt, G.T., 'Electric Power Quality', Stars in a Circle Publications, Indiana, 2nd edition 1996.*
2. *Bollen, M.H.J., 'Understanding Power Quality Problems: Voltage sags and interruptions', IEEE Press, New York, 2000.*
3. *Arrillaga, J, Watson, N.R., Chen, S., 'Power System Quality Assessment', Wiley, New York, 2000.*

Course Outcomes:

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

1. Understand different types of power quality problems with their source of generation.
2. Design different methodologies for detection, classification and mitigation of power quality problems.
3. Expected to practically design active & passive filters for harmonic elimination.

EE626 POWER SYSTEM RESTRUCTURING AND PRICING

L	T	P	C
3	0	0	3

Course Objectives: To understand the electricity power business and technical issues in a restructured power system in both indian and world scenario.

Prerequisites: Power system Analysis, Power system Transmission and Distribution.

Introduction – Market Models – Entities – Key issues in regulated and deregulated power markets - Market equilibrium - Market clearing price - Electricity markets around the world.

Operational and planning activities of a Genco - Electricity Pricing and Forecasting - Price Based Unit Commitment Design - Security Constrained Unit Commitment design. - Ancillary Services for Restructuring-Automatic Generation Control (AGC).

Introduction - Components of restructured system - Transmission pricing in Open-access system-Open transmission system operation - Congestion management in Open-access transmission systems - FACTS in congestion management - Open-access Coordination Strategies - Power Wheeling - Transmission Cost Allocation Methods.

Open Access Distribution - Changes in Distribution Operations - The Development of Competition – Maintaining Distribution Planning.

Power Market Development – Electricity Act, 2003 - Key issues and solution - Developing power exchanges suited to the Indian market - Challenges and synergies in the use of IT in power - Competition - Indian power market - Indian energy exchange- Indian power exchange- Infrastructure model for power exchanges - Congestion Management - Day Ahead Market - Online power trading.

Reference Books:

1. *Loi Lei Lai, 'Power System Restructuring and Deregulation', John Wiley & Sons Ltd., 2001.*
2. *Mohammad Shahidehpour, Hatim Yamin, 'Market operations in Electric power systems', John Wiley & son ltd., 2002.*
3. *Lorrin Philipson, H. Lee Willis, 'Understanding Electric Utilities and Deregulation', Taylor & Francis, 2006.*
4. *Mohammad Shahidehpour, Muwaffaq Alomoush, 'Restructured Electrical Power Systems', Marcel Dekker, Inc., 2001.*

Course Outcomes:

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

1. Explain the deregulated electricity market models functioning around the world.
2. Understand the operational and planning activities in power generation.
3. Solve transmission pricing and understand strategies in congestion management.
4. Study the development of competition in electricity distribution companies.
5. Outline the salient features of Indian Electricity Act and the formation and operation of Indian power exchanges.

E627 COMPUTER RELAYING AND WIDE AREA MEASUREMENT SYSTEMS

L	T	P	C
3	0	0	3

Course Objectives: The goal of this course is to understand the operating principles of a computer relays and wide area measurement systems. Learning about main classification of relay types, wide area measurement systems and their behavior, mathematical background for understanding relaying algorithms and also examining line relaying algorithms and protection of power system components.

Prerequisites: Digital Signal Processing, Power system protection.

Historical background - Expected benefits - Computer relay architecture - Analog to digital converters - Anti-aliasing filters - Substation computer hierarchy - Fourier series - Exponential fourier series - Sine and cosine fourier series – Phasor.

Walsh functions - Fourier transforms - Discrete fourier transform - Random processes - Filtering of random processes - Kalman filtering - Digital filters - Windows and windowing, - Linear phase Approximation - Filter synthesis – Wavelets - Elements of artificial intelligence.

Introduction - Phasor representation of sinusoids - Fourier series and Fourier transform and DFT Phasor representation - Phasor Estimation of Nominal Frequency Signals - Formulas for updating phasors - Nonrecursive updates - Recursive updates - Frequency Estimation.

A generic PMU - The global positioning system - Hierarchy for phasor measurement systems, - Functional requirements of PMUs and PDCs - Transient Response of Phasor Measurement Units-of instrument transformers, filters, during electromagnetic transients - Transient response during power swings.

State Estimation - History, Operator's load flow - Weighted least square least square, -Linear weighted least squares - Nonlinear weighted least squares - Static state estimation - State estimation with Phasors measurements - Linear state estimation - Adaptive protection - Differential and distance protection of transmission lines - Adaptive protection - Adaptive out-of-step protection.

Reference Books:

1. *A.G. Phadke, J.S. Thorp, 'Computer Relaying for Power Systems', John Wiley and Sons Ltd., Research Studies Press Limited, 2nd Edition, 2009.*
2. *A.G. Phadke, J.S. Thorp, 'Synchronized Phasor Measurements and Their Applications', Springer Publications, 2008.*

Course Outcomes:

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

1. Demonstrate knowledge of fundamental aspects of theories, principles and practice of computer relaying.
2. Define and understand the concept of Wide area measurement systems.
3. Understand and design wide are measurement systems application in Smart grid.

EE629 SWARM INTELLIGENT TECHNIQUES

L	T	P	C
3	0	0	3

Course Objectives: To cater the knowledge of swarm intelligent techniques like genetic algorithm, particle swarm optimization, artificial bee colony algorithms, artificial immune systems, firefly algorithms, cuckoo search algorithms etc. and their applications in electrical engineering.

Prerequisites: Basic Electrical and Electronics, Engineering mathematics.

Introduction to intelligent systems- Soft computing techniques- Conventional Computing versus Swarm Computing - Classification of meta-heuristic techniques - Single solution based and population based algorithms – Exploitation and exploration in population based algorithms - Properties of Swarm intelligent Systems - Application domain - Discrete and continuous problems - Single objective and multi-objective problems.

Evolutionary programs – Genetic algorithms, genetic programming and evolutionary programming - Genetic Algorithm versus Conventional Optimization Techniques - Genetic representations and selection mechanisms; Genetic operators- different types of crossover and mutation operators - Optimization problems using GA-discrete and continuous - Single objective and multi-objective problems - Procedures in evolutionary programming.

Biological ant colony system - Artificial ants and assumptions - Stigmergic communications - Pheromone updating- local-global - Pheromone evaporation - Pseudo-probabilistic decision making - Travelling salesman problem - Ant System - ant quantity - ant density - ant cycle - ant colony system. ACO models-Touring ant colony system-max min ant system - Concept of elistic ants–continuous and discrete ACO - Bird flocking and Fish Schooling – anatomy of a particle- equations based on velocity and positions -PSO topologies - swarm types - control parameters - constriction coefficient - ACO and PSO applications in electrical engineering applications.

Task partitioning in honey bees - Balancing foragers and receivers - Artificial bee colony (ABC) algorithms-binary ABC and continuous ABC algorithms - Bacterial foraging techniques – taxes – elimination – dispersals - bacteria motility and swarming - Biological immune systems and artificial immune systems - affinity measures- representations - Basic immune models and algorithms -Bone marrow models - Negative selection algorithms - Clonal selection algorithms -Somatic hyper mutation- Immune network models - Applications in electrical engineering.

Differential search algorithms - Harmony Search algorithms - Cuckoo search algorithms - Firefly algorithms - Gravitational search Algorithms - Hybrid swarm intelligent systems - Applications in electrical engineering.

Reference Books:

1. *Eric Bonabeau, Marco Dorigo and Guy Theraulaz, 'Swarm Intelligence-From natural to Artificial Systems', Oxford university Press, 1999.*
2. *David Goldberg, 'Genetic Algorithms in Search, Optimization and Machine Learning', Pearson Education, 2007.*
3. *James Kennedy and Russel E Eberheart, 'Swarm Intelligence', The Morgan Kaufmann Series in Evolutionary Computation, 2001.*
4. *Castro, LeandroNunes, Timmis and Jonathan, 'Artificial Immune Systems- A new computational approach', Springer publications, 2002.*
5. *N P Padhy, 'Artificial Intelligence and Intelligent Systems', Oxford University Press, 2005.*

Course Outcomes:

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

1. Discriminate the capabilities of bio-inspired system and conventional methods in solving optimisation problems.
2. Examine the importance of exploration and exploitation swarm intelligent system to attain near global optimal solution.
3. Distinguish the functioning of various swarm intelligent systems.
4. Explain and employ various bio-inspired algorithms for engineering applications.

EE630 SMART GRID TECHNOLOGIES

L	T	P	C
3	0	0	3

Course Objectives :

- To study about Smart Grid technologies, different smart meters and advanced metering infrastructure.
- To get familiarized with the power quality management issues in Smart Grid.
- To get familiarized with the high performance computing for Smart Grid applications.

Prerequisites: Distribution systems and Measuring instruments.

Evolution of Electric Grid, Concept - Definitions and Need for Smart Grid - Smart grid drivers – Functions - opportunities - Challenges and benefits - Difference between conventional & smart Grid - Concept of Resilient & Self Healing Grid - Present development & International policies in Smart Grid - Diverse perspectives from experts and global Smart Grid initiatives.

Technology Drivers - Smart energy resources - Smart substations - Substation Automation - Feeder Automation - Transmission systems: EMS, FACTS and HVDC - Wide area monitoring - Protection and control, - Distribution systems: DMS - Volt / VAR control - Fault Detection - Isolation and service restoration - Outage management – High efficiency distribution transformers - Phase Shifting Transformers - Plug in Hybrid Electric Vehicles (PHEV).

Introduction to Smart Meters - Advanced Metering infrastructure (AMI) drivers and benefits - AMI protocols - Standards and initiatives - AMI needs in the smart grid - Phasor Measurement Unit (PMU) - Intelligent Electronic Devices (IED) & their application for monitoring & protection.

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.

Local Area Network (LAN) - House Area Network (HAN) - Wide Area Network (WAN) - Broadband over Power line (BPL) - IP based Protocols - Basics of Web Service and CLOUD Computing to make Smart Grids smarter - Cyber Security for Smart Grid.

Reference Books:

1. *Stuart Borlase 'Smart Grid: Infrastructure, Technology and Solutions', CRC Press , 2012.*
2. *JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, 'Smart Grid: Technology and Applications', Wiley, 2012.*
3. *Vehbi C. Güngör, DilanSahin, TaskinKocak, SalihErgüt, ConcettinaBuccella, Carlo Cecati, and Gerhard P. Hancke, 'Smart Grid Technologies: Communication Technologies and Standards', IEEE Transactions On Industrial Informatics, Vol. 7, No. 4, November 2011.*
4. *Xi Fang, Satyajayant Misra, GuoliangXue, and Dejun Yang 'Smart Grid – The New and Improved Power Grid: A Survey', IEEE Communications Surveys & Tutorials, Vol. 14, No. 4, Fourth Quarter 2012.*

Course Outcomes:

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

1. Get acquainted with the smart technologies.
2. Manage smart grid resources.
3. Assess power quality in smart grid scenario.

EE631 ELECTRICAL SYSTEMS IN WIND ENERGY

L	T	P	C
3	0	0	3

Course Objectives:

- To introduce the various electrical generators and appropriate power electronic controllers employed in wind energy systems.
- To teach the students the steady state analysis and operation of different existing configurations of electrical systems in wind energy and also the recent developments taking place in this field.

Prerequisites: Electrical Machines and Power Electronics.

Principle of operation – Steady state analysis - Characteristics of GCIGs - Operation of GCIGs with different power electronic configurations.

Process of self excitation – Steady state equivalent circuit of SEIG and its analysis - Performance equations - Widening the operating speed range of SEIGs by changing the stator winding connection with suitable solid state switching schemes - Power electronic controllers used in standalone systems.

Need for single phase operation – Typical configurations for the single phase operation of three phase GCIGs and SEIGs – Steady state equivalent circuit and analysis using symmetrical components.

Different operating modes – Steady state equivalent circuit - Performance analysis - DFIG for standalone applications - Operation of DFIGs with different power electronic configurations for standalone and grid-connected operation.

Operation of PMSGs - Steady state analysis - Performance characteristics - Operation of PMSGs with different power electronic configurations for standalone and grid-connected operation.

Reference Books:

1. *Marcelo Godoy Simões and Felix A. Farret, 'Renewable Energy Systems: Design and Analysis with Induction Generators', CRC Press, ISBN 0849320313, 2004.*
2. *Ion Boldea, 'Variable speed Generators', CRC Press, ISBN 0849357152, 2006.*
3. *S.N. Bhadra, D.Kastha and S.Banerje, 'Wind Electrical Systems', Oxford University Press, 2005.*
4. *Siegfried Heier, Rachel Waddington, 'Grid Integration of Wind Energy Conversion Systems', 2nd Edition, Wiley, June 2006, ISBN: 978-0-470-86899-7.*
5. *Freries LL, 'Wind Energy Conversion Systems', Prentice Hall, U.K., 1990.*

Course Outcomes:

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

1. Explain the operation of electrical generators used in wind energy systems.
2. Carry out the steady-state analysis of electrical systems.
3. Design and implement the suitable closed-loop controller for specific applications.

EE632 EMBEDDED PROCESSORS AND CONTROLLERS

L	T	P	C
3	0	0	3

Course Objectives: To enrich the learner with processor and controller design concepts with special concentration on system-on-chip and system-on-programmable chip.

Prerequisites: Digital Electronics, Microprocessors & Microcontrollers, Computer Architecture.

MSP 430 Microcontroller – Functional block diagram – Memory – Interrupts and Resets – Input/ Output units – Instruction set – Addressing modes – Constant generator and Emulated Instructions.

MSP 430 Timers – On-chip data conversion systems – ADC and DAC – On-chip communication peripherals – SPI, I2C, UART – Programming concepts.

ARM7TDMI – Architecture overview - Processor modes – Data types – Registers – Program status registers – Simple programs.

Introduction to Design of Systems on a chip – Core architectures for Digital media and compilation techniques – Microsystems technology and applications – Hardware/ software co-design concepts.

Multi-core System-on-Chip (McSoC) design – Application specific McSoC design – Queue Core Architecture – Synthesis and evaluation results – Reconfigurable multi-core architectures.

Reference Books:

1. *John H. Davies, 'MSP 430 Microcontroller Basics', Elsevier Ltd., 2008.*
2. *William Hohl, 'ARM Assembly Language, Fundamentals and Techniques', CRC Press, 2009.*
3. *Abderazek Ben Abdallah, 'Multi-core systems on-Chip: Practical software and Hardware design', Atlantis press, 2010.*
4. *Ricardo Reis, Marcelo Lubaszewski, Jochen A.G. Jess, 'Design of Systems on a chip: Design and Test', Springer, 2006.*

Course Outcomes:

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

1. Understand the insights and functionality of MSP430 microcontroller.
2. Acquire knowledge on peripherals of MSP430.
3. Appraise the blocks of ARM processor architecture.
4. Adapt the concepts of SoC and hardware/software design.
5. Recognize the use of multi-core SoC.

EE633 DISTRIBUTED GENERATION AND MICRO-GRIDS

L	T	P	C
3	0	0	3

Course Objectives: To understand the planning and operational issues related to Distributed Generation and Micro-grids.

Prerequisites: The students are preferred to have a basic knowledge in Power System Analysis and Distribution Systems.

Need for distributed generation - Renewable sources in distributed generation - Current scenario in distributed generation - Planning of DGs – Siting and sizing of DGs – Optimal placement of DG sources in distribution systems.

Grid integration of DGs – Different types of interfaces - Inverter based DGs and rotating machine based interfaces - Aggregation of multiple DG units - Energy storage elements - Batteries, ultra-capacitors, flywheels.

Technical impacts of DGs – Transmission systems, Distribution systems, De-regulation – Impact of DGs upon protective relaying – Impact of DGs upon transient and dynamic stability of existing distribution systems.

Economic and control aspects of DGs – Market facts, issues and challenges - Limitations of DGs - Voltage control techniques, Reactive power control, Harmonics, Power quality issues - Reliability of DG based systems – Steady state and Dynamic analysis.

Introduction to micro-grids – Types of micro-grids – Autonomous and non-autonomous grids – Sizing of micro-grids - Modeling & analysis - Micro-grids with multiple DGs – Micro-grids with power electronic interfacing units - Transients in micro-grids - Protection of micro-grids – Case studies.

Reference Books:

1. *H. Lee Willis, Walter G. Scott , 'Distributed Power Generation – Planning and Evaluation', Marcel Decker Press, 2000.*
2. *M.Godoy Simoes, Felix A.Farret, 'Renewable Energy Systems – Design and Analysis with Induction Generators', CRC press.*
3. *Robert Lasseter, Paolo Piagi, ' Micro-grid: A Conceptual Solution', PESC 2004, June 2004.*
4. *F. Katiraei, M.R. Iravani, 'Transients of a Micro-Grid System with Multiple Distributed Energy Resources', International Conference on Power Systems Transients (IPST'05) in Montreal, Canada on June 19-23, 2005.*
5. *Z. Ye, R. Walling, N. Miller, P. Du, K. Nelson, 'Facility Microgrids', General Electric Global Research Center, Niskayuna, New York, Subcontract report, May 2005.*

Course Outcomes:

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

1. Understand the current scenario of Distributed Generation and the need to implement DG sources.
2. Investigate the different types of interfaces for Grid integration of DGs.
3. Appraise the technical impacts of DGs upon transmission and distribution systems.
4. Evaluate the various control aspects and techniques of different distributed generation sources.
5. Associate different types of micro-grids and analyze the transients and protection related issues in micro-grids.

EE634 CONTROL DESIGN TECHNIQUES FOR POWER ELECTRONIC SYSTEMS

L	T	P	C
3	0	0	3

Course Objectives: The main objective of this course is to study the application of modern control theory to power electronic converters and drives.

Prerequisites: Classical Control, Systems Theory, Power Converters.

Review of basic control theory – Control design techniques such as P, PI,PID and lead lag compensator design. Review of state space control design approach – State feedback controller and observer design.

Control of DC-DC converters - State space modeling of Buck, Buck-Boost, Cuk, Sepic, Zeta Converters - Equilibrium analysis and closed loop voltage regulations using state feedback controllers and sliding mode controllers.

Control of rectifiers - State space modeling of single phase and three phase rectifiers - State feedback controllers and observer design for output voltage regulation for nonlinear loads - Analysis of continuous and discontinuous mode of operation.

Modeling of Brushless DC motors and its speed regulations – State space model, sensor less speed control of BLDC motor and Sliding mode control design for BLDC motor - Modeling and control of switched reluctance motor.

Modeling of multi input DC-DC converters and its application to renewable energy - Output voltage regulation of multi input DC-DC converter using state feedback controllers.

Reference Books:

1. *Sira -Ramirez, R.Silva Ortigoza, 'Control Design Techniques in Power Electronics Devices', Springer, 2006.*
2. *Siew-Chong Tan, Yuk-Ming Lai, Chi Kong Tse, 'Sliding mode control of switching Power Converters', CRC Press, 2011.*
3. *Bimal Bose, 'Power electronics and motor drives', Elsevier, 2006.*
4. *Ion Boldea and S.A Nasar, 'Electric drives', CRC Press, 2005.*

Course Outcomes:

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

1. Recognize different control techniques and design of compensators, controllers and observers.
2. Model and analyze various closed loop controllers.
3. Design controllers for different rectifiers and to analyze various modes of operation.
4. Model and design of various controllers for BLDC and Reluctance motors.

EE635 ENERGY AUDITING AND MANAGEMENT

L	T	P	C
3	0	0	3

Course Objectives:

- To emphasize the energy management on various electrical equipments and metering.
- To illustrate the energy management in lighting systems and cogeneration.
- To study the concepts behind the economic analysis and load management.

Prerequisites: Electrical Machines, Transmission and Distribution of Electrical Energy, Utilization of Electrical Energy.

Basics of Energy – Need for energy management – Energy accounting - Energy monitoring, targeting and reporting - Energy audit process.

Energy management for electric motors – Transformer and reactors - Capacitors and synchronous machines, energy management by cogeneration – Forms of cogeneration – Feasibility of cogeneration – Electrical interconnection.

Energy management in lighting systems – Task and the working space - Light sources – Ballasts – Lighting controls – Optimizing lighting energy – Power factor and effect of harmonics, lighting and energy standards.

Metering for energy management – Units of measure - Utility meters – Demand meters – Paralleling of current transformers – Instrument transformer burdens – Multi tasking solid state meters, metering location vs requirements, metering techniques and practical examples.

Economic analysis – Economic models - Time value of money - Utility rate structures – Cost of electricity – Loss evaluation, load management – Demand control techniques – Utility monitoring and control system – HVAC and energy management – Economic justification.

Reference Books:

1. *Barney L. Capehart, Wayne C. Turner, and William J.Kennedy, 'Guide to Energy Management', 5th Edition, The Fairmont Press, Inc., 2006.*
2. *Amit K. Tyagi, 'Handbook on Energy Audits and Management', The Energy and Resources Institute, 2003.*
3. *IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities, IEEE, 1996.*

Course Outcomes:

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

1. Understand the basics of Energy auditing and Energy management.
2. Employ energy management strategies for electric machines and cogeneration.
3. Employ energy management strategies in lighting systems.
4. Devise energy management strategies for metering and instrumentation.
5. Analyze and justify the economics of different energy management strategies.

EE636 ELECTRIC AND HYBRID VEHICLES

L	T	P	C
3	0	0	3

Course Objectives: This course introduces the fundamental concepts, principles, analysis and design of hybrid and electric vehicles.

Prerequisites: Power Conversion Techniques, Electrical Machines.

History of hybrid and electric vehicles - Social and environmental importance of hybrid and electric vehicles - Impact of modern drive-trains on energy supplies - Basics of vehicle performance - Vehicle power source characterization - Transmission characteristics - Mathematical models to describe vehicle performance.

Basic concept of hybrid traction - Introduction to various hybrid drive-train topologies - Power flow control in hybrid drive-train topologies - Fuel efficiency analysis - Basic concepts of electric traction - Introduction to various electric drive-train topologies - Power flow control in hybrid drive-train topologies - Fuel efficiency analysis.

Introduction to electric components used in hybrid and electric vehicles - Configuration and control of DC motor drives - Configuration and control of Introduction motor drives - Configuration and control of Permanent Magnet motor drives - Configuration and control of Switch Reluctance motor drives - Drive system efficiency.

Matching the electric machine and the internal combustion engine (ICE) - Sizing the propulsion motor - Sizing the power electronics - Selecting the energy storage technology – Communications - supporting subsystems.

Introduction to energy management strategies used in hybrid and electric vehicle - Classification of different energy management strategies - Comparison of different energy management strategies - Implementation issues of energy strategies.

Reference Books:

1. *Sira -Ramirez, R. Silva Ortigoza, 'Control Design Techniques in Power Electronics Devices', Springer, 2006.*
2. *Siew-Chong Tan, Yuk-Ming Lai, Chi Kong Tse, 'Sliding mode control of switching Power Converters', CRC Press, 2011.*
3. *Bimal Bose, 'Power electronics and motor drives', Elsevier, 2006.*
4. *Ion Boldea and S.A Nasar, 'Electric drives', CRC Press, 2005.*

Course Outcomes:

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

1. Understand mathematical models, performance and characteristics of hybrid and electric vehicles.
2. Analyze the concepts, topologies and power flow control of electric traction systems.
3. Appraise the configuration and control of various hybrid electric motor drives.
4. Plan and design appropriate vehicle management system.

EE637 PRINCIPLES OF VLSI DESIGN

L	T	P	C
3	0	0	3

Course Objectives: Enables the student to get exposure on low power electronic system design and its application.

Prerequisites: Digital Electronics, Electronic Circuits.

MOS and Fabrication: VLSI technology- NMOS, CMOS and BICMOS circuit fabrication - Comparison of IC technologies - Operation characteristics, design equations, models and second order effects of MOS transistors - Fabrication of resistors and capacitors - Latch up, driver circuits.

Hardware Description languages: VHDL- Modeling styles – Design of simple / complex circuits using VHDL - Overview of Verilog HDL - Design of simple circuits using Verilog HDL.

CMOS Logic Circuits: Implementation of logic circuits using MOS and CMOS, Pass transistor and transmission gates ,design of combinational and sequential circuits – Memory design.

Programmable Devices: Simple and Complex Programmable logic devices (SPLD and CPLDs) - Field Programmable Gate Arrays (FPGAs) - Internal components of FPGA - Case study: A CPLD and a 10 million gates type of FPGA.

ASIC: Types of ASICs - Design flow - Programmable ASICs - Programmable ASIC logic cells and interconnect for Xilinx and Altera families.

Reference Books:

1. *Neil Weste, David Harris, 'CMOS VLSI Design: A Circuits and Systems Perspective', Addison-Wesley, 4th Edition,2010.*
2. *M. J. Smith, 'Application Specific Integrated Circuits', Addison Wesley, 1997.*
3. *Uyemura, 'Introduction to VLSI Circuits and Systems', Wiley, 2002.*
4. *J. Bhaskar, 'A Verilog HDL Primer', Star Galaxy, 2nd Edition, 2000.*

Course Outcomes:

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

1. Understand the concepts and characteristics of MOS devices.
2. Model the system using Hardware Description languages.
3. Design the CMOS logic circuits and memory units.
4. Acquire knowledge on PLDs.
5. Appraise the possibilities of ASIC design.

EE638 ADVANCED TOPICS IN POWER ELECTRONICS

L	T	P	C
3	0	0	3

Course Objectives: To give an introduction to the recent developments of power electronics from components, topology, control techniques to thermal & EMC. This course drives on the application requirements of power electronics. This is a higher level of subject that will help to work in demanding areas of power electronics.

Prerequisites: Power Electronics course in UG with knowledge on basics of semiconductor switches, basics of converter topology (AC-DC,AC-AC & DC-DC), basic control techniques of Power Electronic equipment, basics of reactive elements, storage and high frequency magnetic, basics of EMC & any power simulation environment.

Introduction to switches - Advanced Silicon devices - Silicon HV thyristors, MCT, BRT & EST- SiC devices - diodes, thyristors, JFETs & IGBTs - Gallium nitrate devices - Diodes, MoSFETs.

Advance converter topologies for PEE - Interleaved converters, Z-Source converters, multi level converters (Cascaded H-Bridge, Diode clamped, NPC, Flying capacitor) multi pulse PWM current source converters, advanced drive control schemes.

Advances in reactive elements - Advanced magnetic material, technology and design (Powder ferrite, Amorphous, Planar designs) Advance capacitive designs (Multilayer chip capacitors, double layers for storage, Aluminum electrolytic).

Advance storage systems - Developments in battery systems, Ultra capacitors, Fly wheel energy storage, Hybrid storage systems for EV/HEV, Power management in hybrid systems, Energy storage in renewable.

Thermal engineering with EMI/EMC techniques - Advanced thermal solutions (fan cooled, liquid cooled, heat pipes, hybrid techniques) EMC techniques (Conducted, Radiated emissions & Susceptibility), System design for EMC.

Reference Books:

1. *Andrzej M Trzynadlowski, 'Introduction to Modern Power Electronics', John Wiley and sons. Inc, New York, 1998.*
2. *R D MiddleBrook& Slobodan CUK, 'Advances in Switched Mode Power Conversion', Vol I, II, & III, Tesla Co (optimum power conversion).*
3. *B. JayantBalinga, 'Advanced High Voltage Power Device Concepts', Springer New York 2011. ISBN 978 -1-4614-0268-8.*
4. *BIN Wu, 'High Power Converters and AC Drives', IEEE press Wiley Interscience, a John Wiley& sons Inc publication 2006.*
5. *Wurth Electronics, 'Trilogy of Magnetics, Design guide for EMI filter design in SMPS & RF circuits', 4th extended and revised edition.*

Course Outcomes:

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

1. Understand the principles of operation of advanced Silicon devices.
2. Appraise various advanced converter topologies and the suitable control schemes.
3. Recognize recent developments in design aspects of reactive elements such as the material, the structure etc and the effect on performance.
4. Understand nuances of advanced energy storage systems such as battery energy storage system (BESS), ultra capacitors, etc and strategies for power management in such systems.
5. Distinguish between various possible solutions pertaining to thermal management and EMI/EMC problems and devise solutions for simple power electronic systems.

EE639 DESIGN TECHNIQUES FOR SMPS

L	T	P	C
3	0	0	3

Course Objectives: To give a practical step by step approach for design and assembly of Power Supplies and apply the necessary recent technology to comply the standards and certification requirements.

Prerequisites: Power Electronics course in UG with knowledge on Basics of semiconductors, Basics of Power supplies-LPS & SMPS, Basic topologies in SMPC, Control of power semiconductors, Basics of high frequency magnetic, Basics of EMC &any power simulation environment.

Introduction of Available Sources& demanding loads: Sources - AC mains, Lab supplies, Batteries, Solar Cells Loads - Requirements of load, battery as load - Selection of Topology: Step-Up/Step-Down, Multiple outputs, Continuous & discontinuous modes of operation, Isolated converters, Various configurations of Converters - Selection of Components: Selection of Resistors, Chokes, Capacitors, Diodes, MoSFETs & IGBTs, Connectors, Design of Magnetics Fundamentals & ideal conditions, design of High frequency chokes & transformers, Selection of wire gauge, sealing of magnetic.

Guide to Instrumentation: Basics of measurements using DMM, Oscilloscope, Electronic loads, etc. - Design of Magnetics Fundamentals & ideal conditions, design of High frequency chokes & transformers, Selection of wire gauge, sealing of magnetic - Design of Feedback circuits - Basic control requirements, Current & voltage mode control fundamentals & system stability conditions - Design of Control and Monitoring circuits Practical Control circuitry & Monitoring circuitry requirements.

Evaluations and Thermal management: Performance evaluations of SMPS& thermal loss calculations and cooling options& packaging of converter EMI control requirements - Overview of EMC, differentiating signal and noise, Layout concepts Low & High frequency filtering requirements, Optimal filter design - Worst case analysis - Introduction to datasheet reading, operation tuned to datasheet, typical worst case analysis.

Standards governing the power supplies - IEC standards for Electrical &Environmental testing, certification standards, Ingress protection standards - Recent trend in Power supplies - Recent advancements in components - Recent advancements in topologies - Digital control of power supplies - Power Integration &its Low power applications.

Analysis and Simulation using PSIM: BUCK, BOOST&BUCK, BOOST, Typical discrete power factor corrector circuit.

Reference Books:

1. *Ned Mohan ,Undeland and Robbins, 'Power Electronics Converters, Applications and Design',2nd Edition, JohnWiley&sons,1995.*
2. *AbrahamIPressman, KeithBillings, TaylorMorey, 'SwitchingPowerSupplyDesign', 3rd Edition,McGraw-Hill 2009.*
3. *L.Umanandand SR Bhat, 'Design of Magnetic Components for Switched Mode Power Converters', Wiley Eastern Limited.*
4. *International Standard, IEC 60571Edition2.12006-12.*

Course Outcomes:

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

1. Choose appropriate components and configure various converter topologies.
2. Design various control, monitoring and measurement circuitry for Switched Mode Power Supplies
3. Evaluate thermal performance of SMPS units and design appropriate filters
4. Appreciate standards and recent advancements related to SMPS.
5. Analyze and simulate the various converter topologies using PSIM.

EE640 ENERGY STORAGE SYSTEMS

L	T	P	C
3	0	0	3

Course Objectives: To emphasize basic physics, chemistry, and engineering issues of energy storage devices, such as batteries, thermoelectric convertors, fuel cells, super capacitors.

Prerequisites: Fundamental Chemistry and Material Science.

Prospect for both traditional and renewable energy sources - Detailed analysis of Indian energy market and future need through 2020 - Energy, economic growth and the environment, implications of the Kyoto Protocol, and structural change in the electricity supply industry.

Batteries - Performance, charging and discharging, storage density, energy density, and safety issues, classical batteries - Lead Acid, Nickel-Cadmium, Zinc Manganese dioxide, and modern batteries - Zinc-Air, Nickel Hydride, Lithium Battery.

Thermoelectric - Electron conductor and phonon glass, classical thermoelectric materials - four-probe resistivity measurement, Seebeck coefficient measurement and thermal conductivity measurement.

Super capacitors - Types of electrodes and some electrolytes, Electrode materials - High surface area activated carbons, metal oxide and conducting polymers, Electrolyte - Aqueous or organic, disadvantages and advantages of super capacitors - Compared to battery systems, applications - Transport vehicles, private vehicles and consumer electronics - Energy density, power density, price and market.

Fuel cells - Direct energy conversion - Maximum intrinsic efficiency of an electrochemical converter, physical interpretation - Carnot efficiency factor in electrochemical energy convertors, types of fuel cells - Hydrogen oxygen cells, hydrogen air cell, alkaline fuel cell and phosphoric fuel cell.

Reference Books:

1. *Tetsuya Osaka, Madhav Datta, 'Energy Storage Systems in Electronics', Gordon and Breach Science Publishers, 2000.*
2. *R. M. Dell, D.A.J. Rand, 'Understanding Batteries', RSC Publications, 2001.*
3. *James Larminie, Andrew Dick, 'Fuel Cell System Explained', J. Wiley, 2003.*
4. *D.M. Rowe, 'Thermoelectrics Handbook: Macro to Nano', CRC Press, 2006.*

Course Outcomes:

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

1. Recognize various issues related to energy market, its growth and its structural implications in India.
2. Analyze the performance of different battery storage systems.
3. Employ different thermoelectric measurement techniques appropriately.
4. Interpret the applications of super capacitors for appropriate storage systems.
5. Understand and differentiate different types of fuel cells.

EE641 DIGITAL SIMULATION OF POWER ELECTRONIC SYSTEMS

L	T	P	C
3	0	0	3

Course Objectives: To provide knowledge on modeling and simulation of power simulation circuits and systems.

Prerequisites: Knowledge in Power Electronics and Machines.

Review of numerical methods - Application of numerical methods to solve transients in D.C. - Switched R, L, R-L, R-C and R-L-C circuits - Extension to AC circuits.

Modeling of diode in simulation - Diode with R, R-L, R-C and R-L-C load with AC supply - Modeling of SCR, TRIAC, IGBT and Power Transistors in simulation - Application of numerical methods to R, L, C circuits with power electronic switches - Simulation of gate/base drive circuits, simulation of snubber circuits.

State space modeling and simulation of linear systems - Introduction to electrical machine modeling: induction, DC, and synchronous machines, simulation of basic electric drives, stability aspects.

Simulation of single phase and three phase uncontrolled and controlled (SCR) rectifiers, converters with self commutated devices - simulation of power factor correction schemes, simulation of converter fed dc motor drives, simulation of thyristor choppers with voltage, current and load commutation schemes, simulation of chopper fed dc motor.

Simulation of single and three phase inverters with thyristors and self-commutated devices, space vector representation, pulse-width modulation methods for voltage control, waveform control - Simulation of inverter fed induction motor drives.

Reference Books:

1. *Simulink Reference Manual, Math works, USA.*
2. *Robert Ericson, ‘Fundamentals of Power Electronics’, Chapman & Hall, 1997.*
3. *Issa Batarseh, ‘Power Electronic Circuits’, John Wiley, 2004.*

Course Outcomes:

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

1. Develop algorithm and software models for power electronics and drives applications.
2. Analyze the transient and steady performance of the designed models.
3. Choose suitable devices or models for appropriate applications.

EE642 PWM CONVERTERS AND APPLICATIONS

L	T	P	C
3	0	0	3

Course Objectives:

- To understand the concepts and basic operation of PWM converters, including basic circuit operation and design.
- To understand the steady-state and dynamic analysis of PWM converters along with the applications like solid state drives and power quality.

Prerequisites: Power Converters

AC/DC and DC/AC power conversion - Overview of applications of voltage source converters - Pulse modulation techniques for bridge converters.

Bus clamping PWM - Space vector based PWM - Advanced PWM techniques - Practical devices in converter - Calculation of switching and conduction losses.

Compensation for dead time and DC voltage regulation - Dynamic model of a PWM converter - Multilevel converters - Constant V/F induction motor drives.

Estimation of current ripple and torque ripple in inverter fed drives - Line–side converters with power factor compensation.

Active power filtering - Reactive power compensation - Harmonic current compensation**.**

Reference Books:

1. *Mohan, Undeland and Robbins, 'Power Electronics; Converters, Applications and Design', John Wiley and Sons, 1989.*
2. *Erickson R W, 'Fundamentals of Power Electronics', Chapman and Hall, 1997.*
3. *Vithyathil J, 'Power Electronics: Principles and Applications', McGraw Hill, 1995.*

Course Outcomes:

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

1. Understand the basic operations of various PWM techniques for Power Converters.
2. Steady-State and transient modelling and analysis of power converters with various PWM techniques.
3. Analysis and Design of Control Loops for PWM power converters along with the applications like solid state drives and power quality.

EE643 EMBEDDED SYSTEM DESIGN

L	T	P	C
3	0	0	3

Course Objectives: To enable the learner to understand the concepts of embedded processors with its application.

Prerequisites: Digital Systems, Microprocessors/Microcontrollers.

Embedded System Architectures – ARM processor and SHARC processor - Architectural design - Memory organization - Data operation – Bus configurations - System on-chip, scalable bus architectures - Design example: Alarm clock, hybrid architectures.

Sensor and Actuator I/O – ADC, DAC, timers, Servos, Relays, stepper motors, H-Bridge, CODECs, FPGA, ASIC, diagnostic port.

Real time operating systems (RTOS) – Real time kernel – OS tasks – Task states – Task scheduling – Interrupt processing – Clocking communication and synchronization – Control blocks – Memory requirements and control – Kernel services.

Embedded Networks – Distributed Embedded Architecture – Hardware and Software Architectures - Networks for embedded systems– I2C, CAN Bus, Ethernet, Internet, Network – Based design – Communication analysis - system performance analysis - Hardware platform design - Allocation and scheduling - Design Example: Elevator Controller.

System Design – Specification, Requirements and Architectural design of PBX systems - Set-top box - Personal digital assistants.

Reference Books:

1. *Wayne Wolf, 'Computers as Components: Principles of Embedded Computing System Design', Morgan Kaufman Publishers, 3rd Edition, 2012.*
2. *C.M.Krishna, Kang G. Shin , 'Real time systems', McGrawHill,2010.*
3. *Gajski D. D., Vahid F., Narayan S., 'Specification and Design of Embedded Systems', PrenticeHall,2007.*
4. *Herma K., 'Real Time Systems: Design for Distributed Embedded Applications', Kluwer Academic, 2nd Edition, 2011.*
5. *WilliamHohl, 'ARM Assembly Language, Fundamentals and Techniques', CRC Press, 2009.*

Course Outcomes:

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

1. Understand the architecture of ARM and SHARC processors.
2. Explore the possible peripherals with the processor.
3. Acquire the knowledge of requirements of the real time OS.
4. Appraise the embedded networks.
5. Apply the concepts and understand the applications.

EE644 DIGITAL CONTROL SYSTEMS

L	T	P	C
3	0	0	3

Course Objectives: This course gives an idea about designing digital controllers, which are feasible to implement in digital computers, using both classical and modern techniques.

Prerequisites: Classical Control, Modern Control.

Introduction to Discrete time systems - Analogies with continuous-time systems - Mathematical models for LTI discrete-time systems - Convolution representation and difference equations in advanced and delayed form, Z-transformation - Analysis of first, second, and higher order systems - Stability of discrete-time systems - The Jury's criterion.

Modeling of Sampled Data Systems - Sampled Data System - Models of Continuous Time Systems - Naturally Occurring Discrete Time Systems - Discretization of Continuous Time Systems - Approaches to Controller Design and Testing.

Digital Signal Processing - Linear System-Basic Concepts, Basic Discrete Time Signals, Input–Output Convolution Models - Z-Transform - Motivation and Definition of Z-Transform, Z-Transform Theorems and Examples, Transfer Function , Inverse of Z-Transform - Frequency Domain Analysis - Basics, Fourier Series and Fourier Transforms, Sampling and Reconstruction, Filtering, Discrete Fourier Transform.

Transfer Function Approach to Controller Design - Structures and Specifications - Control Structures , Proportional Control , Other Popular Controllers - Proportional, Integral, Derivative Controllers- Discretization Techniques, Discretization of PID Controllers - Pole Placement Controllers - Pole Placement Controller with Performance Specifications, PID Tuning Through Pole Placement Control , Special Cases of Pole Placement Control - Minimum Variance Control - Generalized Minimum Variance Controller - Model Predictive Control - Generalized Predictive Control - Linear Quadratic Gaussian Control.

State Space Approach to Controller Design - State Space Techniques in Controller Design - Pole Placement, Estimators, Regulator Design, Linear Quadratic Regulator, Kalman Filter.

Reference Books:

1. *Kannan M. Moudgalya, 'Digital Control', John Wiley & Sons Ltd,2007.*
2. *Ogata K., 'Discrete-time Control Systems', 2nd Edition, Prentice Hall Inc., New Jersey, 1992.*

Course Outcomes:

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

1. Understand the difference between continuous time controller and discrete time controllers.
2. Design of digital controllers.
3. Implementation based on various applications.