M. Tech.

IN

POWER ELECTRONICS

PROPOSED

CURRICULUM -2019

(For students admitted in 2020-21)

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

TIRUCHIRAPPALLI – 620 015

TAMIL NADU, INDIA

CURRICULUM

The total minimum credits for completing the M.Tech. programme in Power Electronics is 64 .

SEMESTER I

Sl. No.	Course Code	Course Title	Credits
1	MA603	Advanced Engineering Mathematics	3
2	EE651	Power Converters	3
3	EE653	Linear and Non-Linear Systems Theory	3
4		ELECTIVE 1	3
5		ELECTIVE 2	3
6		ELECTIVE 3	3
7	EE657	Design and Simulation of Power Electronic Circuits Laboratory	2
Total			**20**

SEMESTER II

Sl. No.	Course Code	Course Title	Credits
1	EE652	Switched Mode Power Conversion	3
2	EE654	Power Electronic Drives	3
3	EE656	Industrial Control Electronics	3
4		ELECTIVE 4	3
5		ELECTIVE 5	3
6		ELECTIVE 6	3
7	EE658	Power Converters and Drives Laboratory	2
Total			**20**

SEMESTER III

Course Code	Course Title	Credits
EE659	PROJECT WORK - PHASE I	12
	Total	**12**

SEMESTER IV

Course Code	Course Title	Credits
EE660	PROJECT WORK - PHASE II	12
	Total	**12**

LIST OF ELECTIVES

Sl. No.	Course Code	Course Title	Credits
1.	EE601	Advanced Power System Analysis	3
2.	EE602	Power System Operation And Control	3
3.	EE604	Advanced Power System Protection	3
4.	EE661	Flexible AC Transmission Systems	3
5.	EE662	High Voltage DC Transmission	3
6.	EE664	Advanced Digital Signal Processing	3
7.	EE665	Advanced Digital System Design	3
8.	EE667	Analysis And Design Of Artificial Neural Networks	3
9.	EE668	Digital Controller In Power Electronics Applications	3
10.	EE669	Computer Networking	3
11.	EE670	Electrical Distribution Systems	3
12.	EE671	Fuzzy Systems	3
13.	EE672	Transient Over Voltages In Power Systems	3
14.	EE673	Renewable Power Generation Technologies	3
15.	EE674	Power System Planning And Reliability	3

16.	EE675	Modeling And Analysis Of Electrical Machines	3
17.	EE676	Power Quality	3
18.	EE677	Power System Restructuring And Pricing	3
19.	EE678	Computer Relaying And Wide Area Measurement Systems	3
20.	EE679	Swarm Intelligent Techniques	3
21.	EE680	Smart Grid Technologies	3
22.	EE681	Electrical Systems In Wind Energy	3
23.	EE684	Distributed Generation And Micro-Grids	3
24.	EE685	Control Design Techniques For Power Electronic Systems	3
25.	EE686	Energy Auditing And Management	3
26.	EE687	Electric and Hybrid Vehicles	3
27.	EE688	Principles Of VLSI Design	3
28.	EE689	Advanced Topics in Power Electronics Applications	3
29.	EE690	Design Techniques For SMPS	3
30.	EE691	Energy Storage Systems	3
31.	EE692	Digital Simulation of Power Electronic Systems	3
32.	EE693	PWM Converters and Applications	3
33.	EE695	Digital Control Systems	3
34.	EE696	Power System Automation	3
35.	EE698	Grid Converters For Renewable Energy Applications	3
36.	EE699	Topics In Power Electronics And Distributed Generation	3
37.	EE700	Wireless Sensor Networks And Applications	3
38.	EE701	Soft Switching Power Converters	3
39.	EE702	Solar PV System	3
40.	EE703	E-Vehicle Technology and Mobility	3
41	EE704	Design of Embedded Controllers for Smart Micro-grid	3

Course Code	:	**MA603**
Course Title	:	**ADVANCED ENGINEERING MATHEMATICS**
Number of Credits	:	**3**
Course Type	:	**Core**

Course Objectives:	To learn essential optimization techniques for applying day to day problems. To learn the numerical techniques to solve ordinary differential equations. To learn the fundamentals of probability & statistical methods to apply in practical problems.

Introduction to Linear Programming Techniques- Unconstrained one dimensional optimization techniques - Necessary and sufficient conditions – Unrestricted search methods - Fibonacci and Golden section method.

Unconstrained n dimensional optimization techniques –Descent methods - Steepest descent, conjugate gradient. Constrained optimization Techniques - Necessary and sufficient conditions – Equality and inequality constraints - Kuhn-Tucker conditions - Gradient projection method

Numerical Solution of Ordinary Differential Equations and application to ordinary differential equations - Euler's method - Euler's modified method - Taylor's method and Runge-Kutta method for simultaneous equations and 2nd order equations - Multistep methods - Milne's and Adams' methods.

Random variable – two dimensional random variables – standard probability distributions – Binomial Poisson and normal distributions - moment generating function.

Sampling distributions and applications – confidence interval estimation of population parameters – testing of hypotheses – Large sample tests for mean and proportion – t-test, F-test and Chi-square test – curve fitting-method of least squares.

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. *Jain, M.K., Iyengar, S.R., and Jain, R.K., 'Numerical Methods for Scientific and Engineering Computation', Wiley Eastern, 1992.*
4. *Bowker and Liberman, Engineering Statistics, Prentice-Hall, 1972*
5. *S. C. Gupta, Fundamentals of Statistics, Himalaya Publishing House, Seventh Revised Edition, 2009.*
6. *S.C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand and Sons, Eleventh Revised Edition.*

Course Outcomes:

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

1. Apply appropriate optimization technique and analyze unconstrained one dimensional problems.
2. Apply appropriate optimization technique and analyze unconstrained multi-dimensional problems.
3. Appraise and evaluate constrained optimization problems related to Power Systems/Power Electronics by appropriate methods.
4. Solve ordinary differential equations numerically.
5. demonstrate applications of probability theory

Course Code	**:**	**EE 651**
Course Title	**:**	**POWER CONVERTERS**
Number of Credits	**:**	**3**
Course Type	**:**	**Core**

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.

References Books:

1. *Ned Mohan, Undeland and Robbin, 'Power Electronics: converters, Application and design', John Wiley andsons. 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. To study and analyze transient response of basic power electronic circuits.
2. To understand the working of commonly used power Converters.
3. To analyze and design various power converter systems.

Course Code	**:**	**EE653**
Course Title	**:**	**LINEAR AND NON-LINEAR SYSTEMS THEORY**
Number of Credits	**:**	**3**
Course Type	**:**	**Core**

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.*

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.

Course Code	**:**	**EE657**
Course Title	**:**	**DESIGN AND SIMULATION OF POWER ELECTRONIC CIRCUITS LABORATORY**
Number of Credits	**:**	**2**
Course Type	**:**	**Laboratory**

Course Objectives: The experiments will be conducted based on the following criteria. From the requirement of the load, the ratings of components such as power devices, L and C are identified using standard steady state equations. The performance is verified through simulations in relevant software and the design can be validated.

Prerequisites: Basics of Power electronics

List of Experiments

1) Single-phase and three-phase half-controlled rectifiers
2) Single-phase and three-phase fully-controlled rectifiers
3) Buck, Boost and Buck-Boost converters
4) Single-phase and three-phase Voltage-source inverters
5) Single-phase and three-phase Current-source inverters
6) Single-phase and three-phase AC voltage regulators

Course Outcomes:

On completion of the course, the students are expected to be able to :

1. Test and analyse the basic rectifier and inverter circuits
2. Test and analyse controlled circuits

Course Code	:	**EE652**
Course Title	:	**SWITCHED MODE POWER CONVERSION**
Number of Credits	:	**3**
Course Type	:	**Core**

Course Objectives: Understand the concepts, basic operation, steady-state operation of efficient switched- mode power conversion techniques, including basic circuit operation and magnetics 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 Modelling 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.

References 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.

Course Code	:	**EE654**
Course Title	:	**POWER ELECTRONIC DRIVES**
Number of Credits	:	**3**
Course Type	:	**Core**

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. *BimalK .Bose, 'Modern Power Electronics and AC Drives', Pearson Education (Singapore) Pvt. Ltd., New Delhi, 2003.*
4. *Sundareswaran K, "elementary concepts of Power Electronic Drives", CRC Press, 20*19.

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.

Course Code	**:**	**EE656**
Course Title	**:**	**INDUSTRIAL CONTROL ELECTRONICS**
Number of Credits	**:**	**3**
Course Type	**:**	**Core**

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.

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

Review of uninterrupted power supplies - offline and on-line topologies - analysis of UPS topologies, solid state circuit breakers and solid-state tap changing of transformer - advance energy storage systems, battery, ultra-capacitors, flywheel energy storage, fuel cells characteristics and applications.

Overview of sensors in industrial applications – current sensors, current transformer, hall effect sensors - voltage sensors, non-isolated measurement, hall effect, temperature sensors, thermal protection of power components – speed sensors – position sensors.

Analog controllers - proportional controllers, proportional – integral controllers, PID controllers, derivative overrun, integral windup, cascaded control, feed forward control. Signal conditioners - instrumentation amplifiers – voltage to current, current to voltage, voltage to frequency, frequency to voltage converters.

Solid state welding power source - introduction, classification, basic characteristics, volt ampere relationship and its measurements, control of volt ampere characteristics, volt control, slope control and dual control– pulsing techniques – testing of welding power source. Introduction to heating, classification, characteristics – applications

Introduction to programmable logic controllers, architecture, programming. Supervisory control and data acquisition (SCADA) Systems, components of SCADA systems, SCADA basic functions, SCADA application functions in electrical engineering. Energy saving in electrical drive systems.

Reference Books

1. *Michael Jacob, 'Industrial Control Electronics – Applications and Design', Prentice Hall, 1995. 2. Thomas E. Kissell, 'Industrial Electronics', Prentice Hall India, 2003*
2. *Curtis D. Jhonson 'Process Control Instrumentation technology' Pearson New International Eighth edition,2014*
3. *Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, Ali Emadi 'Modern Electric, Hybrid Electric and Fuel Cell Vehicles-Fundamentals, Theory and Design' CRC Press 2004.*
4. *Mini S. Thomas, John D McDonald, Power Systems SCADA and Smart Grid, CRC Press, Taylor and Francis.*
5. *Welding Handbook, Volume-2, Seventh Edition, American Welding Society.*
6. *Power Electronics Applied to Industrial Systems and Transports. Volume 5: Measurement Circuits, Safeguards and Energy Storage, Imprint - ISTE Press – Elsevier.*

Course Outcomes:

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

1. To understand the working of various power electronic circuits and components used in industrial applications.
2. To analyse various analog controllers and signal conditioning circuits.
3. To design control circuits for industrial applications.

Course Code	**:**	**EE658**
Course Title	**:**	**POWER CONVERTERS AND DRIVES LABORATORY**
Number of Credits	**:**	**2**
Course Type	**:**	**Laboratory**

Course Objectives: Given design details fabricate and test the following power converters and drives

Prerequisites: Basics of Power converters

List of Experiments

1) Single-phase and three-phase half-controlled rectifiers
2) Single-phase and three-phase fully-controlled rectifiers
3) Buck, Boost and Buck-Boost converters
4) Single-phase and three-phase Voltage-source inverters
5) Single-phase and three-phase Current-source inverters
6) Single-phase and three-phase AC voltage regulators

Course Outcomes:

On completion of the course, the students are expected to be able to:

1. Test and analyse the basic rectifier and inverter circuits

2. Test and analyse controlled circuits

Course Code	**:**	**EE601**
Course Title	**:**	**ADVANCED POWER SYSTEM ANALYSIS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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, NewDelhi, 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. To construct models of power system components and apply them
2. To solve ac and dc load flow for single and there phase systems
3. To analyse the faults in the power system networks
4. To apply the concepts of optimization in power system.
5. To explain the concept of state estimation in power system and the role of statistics in state estimation.

Course Code	**:**	**EE602**
Course Title	**:**	**POWER SYSTEM OPERATION AND CONTROL**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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

Course Code	**:**	**EE604**
Course Title	**:**	**ADVANCED POWER SYSTEM PROTECTION**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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', IEE 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.

Course Code	**:**	**EE661**
Course Title	**:**	**FLEXIBLE AC TRANSMISSION SYSTEMS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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

Course Code	**:**	**EE662**
Course Title	**:**	**HIGH VOLTAGE DC TRANSMISSION**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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-CCC 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.

Course Code	:	**EE664**
Course Title	:	**ADVANCED DIGITAL SIGNAL PROCESSING**
Number of Credits	:	**3**
Course Type	:	**Elective**

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' 4th Edition, Pearson Education, 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.

Course Code	**:**	**EE665**
Course Title	**:**	**ADVANCED DIGITAL SYSTEM DESIGN**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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.

Course Code	:	**EE667**
Course Title	:	**ANALYSIS AND DESIGN OF ARTIFICIAL NEURAL NETWORKS**
Number of Credits	:	**3**
Course Type	:	**Elective**

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. To explain the concepts of biological and artificial neural network.
2. To understand the different modes of operation in artificial neural network.
3. To discriminate the first generation and second generation neural networks.
4. To understand the third generation neural networks.
5. To apply neural network in pattern recognition, forecasting, control, clustering, data mining and decision making engineering problems.

Course Code	**:**	**EE668**
Course Title	**:**	**DIGITAL CONTROLLERS IN POWER ELECTRONICS APPLICATIONS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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 Manage interrupts - General Purpose (GP) Timers - Compare Units - Capture Units and Quadrature Enclosed Pulse (QEP) Circuitry - General Event Manager Information.

Code composer studio, Embedded Coding through MATLAB and other modern simulation tools, PWM Generation, Dead band unit, Phase shifted PWM for full bridge converters, PWM for interleaved converters.

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. Will 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.

Course Code	**:**	**EE669**
Course Title	**:**	**COMPUTER NETWORKING**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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.

Course Code	**:**	**EE670**
Course Title	**:**	**ELECTRICAL DISTRIBUTION SYSTEMS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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.

Course Code	:	**EE671**
Course Title	:	**FUZZY SYSTEMS**
Number of Credits	:	**3**
Course Type	:	**Elective**

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.*
4. *Sundareswaran K,"A Learner's Guide to Fuzzy Logic Systems" (Second edition), CRC Press, 2019.*

Course Outcomes:

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

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

Course Code	**:**	**EE672**
Course Title	**:**	**TRANSIENT OVER VOLTAGES IN POWER SYSTEMS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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.

Course Code	**:**	**EE673**
Course Title	**:**	**RENEWABLE POWER GENERATION TECHNOLOGIES**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Objectives: This course makes the student

- to aware of various forms of renewable energy
- to 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.

Course Code	**:**	**EE674**
Course Title	**:**	**POWER SYSTEM PLANNING AND RELIABILITY**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Objectivess: 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 modelling in Electric Power System' John Wiley, 1980.*

Course Outcomes:

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

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

Course Code	**:**	**EE675**
Course Title	**:**	**MODELING AND ANALYSIS OF ELECTRICAL MACHINES**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Objectives: To give a systematic approach for modeling and analysis of all rotating machines under both transient and steady state conditions.
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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 McgrawHill, 5th Edition, 1992.*
2. *R. Krishnan, 'Electric Motor & Drives: Modeling, Analysis and Control', Prentice Hall ofIndia, 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.

Course Code	**:**	**EE676**
Course Title	**:**	**POWER QUALITY**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Objectives: Understand the various power quality phenomenon, their origin and monitoring and mitigation methods. 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.

Course Code	**:**	**EE677**
Course Title	**:**	**POWER SYSTEM RESTRUCTURING AND PRICING**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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. To explain the deregulated electricity market models functioning around the world.
2. To understand the operational and planning activities in power generation.
3. To solve transmission pricing and understand strategies in congestion management.
4. To study the development of competition in electricity distribution companies.
5. To outline the salient features of Indian Electricity Act and the formation and operation of Indian power exchanges.

Course Code	:	**EE678**
Course Title	:	**COMPUTER RELAYING AND WIDE AREA MEASUREMENT SYSTEMS**
Number of Credits	:	**3**
Course Type	:	**Elective**

Course Objectives: The goal of this course is to provide basic knowledge on computer relaying and its applications in wide area measurement systems. The internal architecture and algorithms employed in a numerical relays will be discussed. Understanding about wide area measurement systems, mathematical background for relaying algorithms and also examining line relaying algorithms for protection of power system components

Prerequisites: Digital Signal Processing, Power system protection

Introduction to Computer Relaying: Introduction to DSP, Use of computer relay, Analog to Digital Converters, Sampling, Anti – aliasing filters. Evolution of power system relaying from electromagnetic to static to computer relaying; Relay operating principles for computer relaying; Expected benefits of computer relaying, Computer relay architecture.

Protection of Transmission Line using Computer Relaying: Three zone protection of transmission line, algorithms for impedance calculations- Mann-Morrison algorithm - Three sample technique - Two sample technique - First and second derivative algorithms - Numerical integration methods.

Protection of power system equipment using Frequency domain techniques: Problems associated with differential protection of transformer and bus-bar, magnetic inrush current, LSQ algorithm, Fourier analysis of transformer protection.

Phasor Measurement Units: Introduction to Phasor measurement units (PMUS), global positioning system (GPS), Functional requirements of PMUs and PDCs, phasor estimation of nominal frequency inputs

PMU Applications : Wide Area Measurement Systems (WAMS), WAMS Applications in Smart Grid, WAMS Based Protection Concepts, Adaptive Relaying, State estimation.

Reference Books:

1. *John G. Prokis and Dimitris G. Hanolakis, 'Digital Signal Processing, Principles, Algorithms & Applications' 4th Edition, Pearson Education, 2006.*
2. *A.G. Phadke, J.S. Thorp, 'Computer Relaying for Power Systems', John Wiley and Sons Ltd., Research Studies Press Limited, 2nd Edition, 2009.*
3. *A.G. Phadke, J.S. Thorp, 'Synchronized Phasor Measurements and Their Applications', Springer Publications, 2008.*

Course Outcomes:

Upon finishing the course, students are expected to accomplish the following objectives:

1. Demonstrate knowledge of fundamental aspects of the theories, principles and practice of computer relaying
2. Understand the application of numerical relay to power system equipment protection
3. Understand and design wide area measurement systems application in Smart grid

Course Code	:	**EE679**
Course Title	:	**SWARM INTELLIGENT TECHNIQUES**
Number of Credits	:	**3**
Course Type	:	**Elective**

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.*
6. *IEEE Transaction research papers*

Course Outcomes:

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

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

Course Code	**:**	**EE680**
Course Title	**:**	**SMART GRID TECHNOLOGIES**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Objectives:

- To understand the need and concept of Smart Grid.
- To study different EMS and DMS functions and smart meters.
- To get familiarized with the communication networks for Smart Grid applications

Prerequisites: Fundamentals of Power Distribution Systems.

Introduction - Evolution of Electric Grid, Smart Grid Concept - Definitions and Need for Smart Grid – Functions – Opportunities – Benefits and challenges, Difference between conventional & Smart Grid, Technology Drivers.

Energy Management System (EMS) - Smart substations - Substation Automation - Feeder Automation, SCADA – Remote Terminal Unit – Intelligent Electronic Devices – Protocols, Phasor Measurement Unit – Wide area monitoring protection and control, Smart integration of energy resources – Renewable, intermittent power sources – Energy Storage.

Distribution Management System (DMS) – Volt / VAR control – Fault Detection, Isolation and Service Restoration, Network Reconfiguration, Outage management System, Customer Information System, Geographical Information System, Effect of Plug in Hybrid Electric Vehicles.

Introduction to Smart Meters – Advanced Metering infrastructure (AMI), AMI protocols – Standards and initiatives, Demand side management and demand response programs, Demand pricing and Time of Use, Real Time Pricing, Peak Time Pricing.

Elements of communication and networking – architectures, standards, PLC, Zigbee, GSM, BPL, 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, 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. *Mini S. Thomas, John D McDonald, 'Power System SCADA and Smart Grids', CRC Press, 2015*
4. *Kenneth C.Budka, Jayant G. Deshpande, Marina Thottan, 'Communication Networks for Smart Grids', Springer, 2014.*

Course Outcomes:

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

1. Get acquainted with the smart resources, smart meters and other smart devices.
2. Describe how modern power distribution system functions.
3. Identify suitable communication networks for smart grid applications

Course Code	**:**	**EE681**
Course Title	**:**	**ELECTRICAL SYSTEMS IN WIND ENERGY**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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 –stead 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.*

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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.

Course Code	**:**	**EE684**
Course Title	**:**	**DISTRIBUTED GENERATION AND MICRO-GRIDS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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.GodoySimoes, 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', Subcontract report, May 2005,*
6. *General Electric Global Research Center, Niskayuna, New York.*

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.

Course Code	**:**	**EE685**
Course Title	**:**	**CONTROL DESIGN TECHNIQUES FOR POWER ELECTRONIC SYSTEMS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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.

Modelling of Brushless DC motors and its speed regulations – State space model, sensorless speed control of BLDC motor and Sliding mode control design for BLDC motor. Modelling 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

Course Code	**:**	**EE686**
Course Title	**:**	**ENERGY AUDITING AND MANAGEMENT**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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 – multitasking 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

Course Code	**:**	**EE687**
Course Title	**:**	**ELECTRIC AND HYBRID VEHICLES**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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.

Course Code	**:**	**EE688**
Course Title	**:**	**PRINCIPLES OF VLSI DESIGN**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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.

Course Code	:	**EE689**
Course Title	:	**ADVANCED TOPICS IN POWER ELECTRONICS**
Number of Credits	:	**3**
Course Type	:	**Elective**

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.

References 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

Course Code	**:**	**EE690**
Course Title	**:**	**DESIGN TECHNIQUES FOR SMPS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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,DesignofMagneticsFundamentals&idealconditions,designofHigh 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 magnetics 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 f or 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.

Course Code	:	**EE691**
Course Title	:	**ENERGY STORAGE SYSTEMS**
Number of Credits	:	**3**
Course Type	:	**Elective**

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 (i) 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, MadhavDatta, ‘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 supercapacitors for appropriate storage systems.
5. Understand and differentiate different types of fuel cells.

Course Code	**:**	**EE692**
Course Title	**:**	**DIGITAL SIMULATION OF POWER ELECTRONIC SYSTEMS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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, 2004Simulink Reference Manual , Math works, USA.*

Course Outcomes:

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

1. To develop algorithm and software models for power electronics and drives applications
2. To analyze the transient and steady performance of the designed models.
3. To choose suitable devices or models for appropriate applications

Course Code	**:**	**EE693**
Course Title	**:**	**PWM CONVERTERS AND APPLICATIONS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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, Multilevel Inverter – diode clamped inverter – flying capacitor inverter

Bus clamping PWM and advanced 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.

Course Code	**:**	**EE695**
Course Title	**:**	**DIGITAL CONTROL SYSTEMS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

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. *Digital Control, "Kannan M. Moudgalya", 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

Course Code	**:**	**EE696**
Course Title	**:**	**POWER SYSTEM AUTOMATION**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Objectives: To familiarize the students with the basics of Power System Automation, Building blocks, Supervisory Control And Data Acquisition (SCADA) System, Remote Terminal Units(RTU), Master Stations etc.

Prerequisites: Basic Knowledge of Transmission & Distribution systems and Measuring Instruments

Evolution of Automation systems, History of Power system Automation, Supervisory Control And Data Acquisition (SCADA) Systems, Components of SCADA systems, SCADA Applications, SCADA in power systems, SCADA basic functions, SCADA application functions in Generation, Transmission and Distribution.

Advantages of SCADA in Power Systems, The Power system 'Field', Types of data & signals in the Power system, Flow of Data from the field to the SCADA Control center. Building blocks of SCADA systems, Classification of SCADA systems.

Remote Terminal Unit (RTU), Evolution of RTUs, Components of RTU, Communication, Logic, Termination and Test/HMI Subsystems, Power supplies, Advanced RTU Functionalities.

Intelligent Electronic Devices (IEDs), Evolution of IEDs , IED functional block diagram, The hardware and software architecture of IED, IED Communication subsystem, IED advanced functionalities, Typical IEDs, Data Concentrators and Merging Units, SCADA Communication Systems.

Master Station, Master station software and hardware configurations, Server systems in the master station, Small, medium and large master station configurations, Global Positioning Systems, Master station performance, Human Machine Interface (HMI), HMI components, Software functionalities, Situational awareness, Case studies in SCADA.

Reference Books:

1. *Mini S. Thomas, John D McDonald, Power Systems SCADA and Smart Grid, CRC Press, Taylor and Francis .*
2. *Electric Power Substation Engineering John D. Mc Donald CRC Press, Taylor and Francis*
3. *Control and Automation of Electrical Power Distribution systems, James Northcote- Green, R Wilson, CRC Press, Taylor and Francis.*
4. *Electric Power Distribution, Automation, Protection and Control, James Momoh, CRC press, Taylor and Francis.*
5. *Related Research papers.*

Course Outcomes:

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

1. Understand the concepts of power system automation.
2. Understand the components of SCADA systems.
3. Comprehend the RTU, IED and other components of automation systems
4. Understand the transfer of signals from the field to an operator control terminal.
5. Design an interoperable powers automation system.

Course Code	**:**	**EE698**
Course Title	**:**	**GRID CONVERTERS FOR RENEWABLE ENERGY APPLICATIONS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Objectives: To understand the modeling, controlling of the grid connected converters for PV and wind applications.

Photovoltaic power development, wind power development, grid converter structures, modeling and control of grid-tied converters.

International regulations, response to abnormal grid conditions (voltage deviations, frequency deviations), power quality issues on DC current injection, current harmonics, power factor.

Grid requirements for wind turbine systems**,** grid code evolution, frequency and voltage deviation under normal operation, active and reactive power control in normal operation, behavior under grid disturbance.

Grid synchronization with PV and wind turbine systems, voltage vector under normal and abnormal grid conditions, synchronous reference frame PLL under unbalanced and distorted grid conditions, operation of different PLL techniques.

Overview of control techniques for grid connected converters under unbalanced grid voltage conditions, control of grid converters under grid faults, control structures for unbalanced current injection, power control under unbalanced grid condition, flexible power control with current limitation.

Reference Books:

1. *Remus Teodorescu, Marco Liserre, Pedro Rodriguez., Grid Converters for Photovoltaic and Wind power Systems, first edition, Wiley Publication 2011.*
2. *Amirnaser Yazdani, Reza Iravani., Voltage Sourced Converters in Power Systems, Modeling, Control and Applications, Wiley Publications 2010.*
3. *Ned Mohan, Tore M, Undelnad, William P, Robbins (3 Edition), Power Electronics: Converters, Applications and Design; Wiley 2002.*
4. *BinWu, Yongqiang Lang, Navid Zargari and Samir Kouro., 'Power Conversion and Control of Wind energy systems', John wiley & sons, inc., publication 2011.*

Course Outcomes:

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

1. Investigate the converters structure for grid connected PV and wind systems.
2. Understand the grid requirements for PV and wind turbine systems under normal and abnormal grid conditions.
3. Evaluate the various control aspects and techniques for grid connected converters under normal and abnormal grid conditions.

Course Code	**:**	**EE699**
Course Title	**:**	**TOPICS IN POWER ELECTRONICS AND DISTRIBUTED GENERATION**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Objectives: To understand the planning and operational issues related to distributed generation.

Introduction to distribution systems, distribution system equipment, grounding, sequence analysis and fault calculations, relaying requirements for distributed generation (DG) systems.

Intentional and unintentional islanding, power converter topologies for grid interconnection, inverter modelling, filtering requirements.

Design of power converter components**,** DC bus design, considerations for power loss and reliability in the design procedure, thermal cycling of power semiconductor modules, insulation grade selection, and thermal design implications.

Control of grid interactive power converters, synchronization and phase locking techniques, current control, DC bus control, converter faults, grid parallel and stand alone operation.

Power quality, voltage unbalance, harmonics, flicker, voltage and frequency windows, and recent trends in power electronic DG interconnection.

Reference Books:

1. *Technical literature – papers published in power electronics related journals and IEEE standards.*
2. *Ramanarayanan V., Switched Mode Power Conversion, 2007.*
3. *Arthur R, Bergen, Vittal, Power Systems Analysis (2nd Ed) Prentice Hall, 1999*
4. *Ned Mohan, Tore M, Undelnad, William P, Robbins (3 Edition), Power Electronics: Converters, Applications and Design; Wiley 2002.*
5. *Sedra A. S and Smith K, Microelectronic Circuits: theory and Applications, (7 Edition) Oxford University Press, 2017.*
6. *Proakis J G and Manolakis D K, Digital Signal Processing, Pearson 2007.*
7. *Lucca Corradini, Dragan Maksimovic, Paolo Mattavelli, and Regan Zane, Digital Control of High-Frequency Switched-Mode Power Converters, Wiley-Blackwell, 2015.*
8. *Patrick R. Schaumont, A Practical Introduction to Hardware/Software, Springer 2nd Edition, 2014.*

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.

Course Code	**:**	**EE700**
Course Title	**:**	**WIRELESS SENSOR NETWORKS AND APPLICATIONS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Objective: To understand the concepts of Wireless Sensor Network protocols, issues and its applications.

Challenges for Wireless Sensor Networks-Characteristics requirements-required mechanisms, Difference between mobile ad-hoc and sensor networks, Applications of sensor networks-Enabling Technologies for Wireless Sensor Networks.

Single-Node Architecture - Hardware Components, Energy Consumption of Sensor Nodes, Network Architecture - Sensor Network Scenarios, Gateway Concepts.

Physical Layer and Transceiver Design Considerations, MAC Protocols for Wireless Sensor Networks, Low Duty Cycle Protocols and Wakeup Concepts, Address and Name Management, Assignment of MAC Addresses, Routing Protocols

Topology Control, Clustering, Sensor Tasking and Control, Berkeley Motes, SENSEnuts, Programming Challenges, Node-level software platforms, Node-level Simulators.

WSN Applications -Home Control -Building Automation -Industrial Automation -Medical Applications -Reconfigurable Sensor Networks -Highway Monitoring -Military Applications -Civil and Environmental Engineering Applications

TEXTBOOKS

1. *Holger Karl & Andreas Willig, "Protocols and Architectures for Wireless Sensor Networks", John Wiley, 2005.*
2. *Kazem Sohraby, Daniel Minoli, & Taieb Znati, “Wireless Sensor Networks- Technology, Protocols, And Applications”, John Wiley, 2007.*

REFERENCES

1. *Anna Hac, “Wireless Sensor Network Designs”, John Wiley, 2003.*
2. *Bhaskar Krishnamachari,” Networking Wireless Sensors”, Cambridge Press,2005.*
3. *K. Akkaya and M. Younis, “A survey of routing protocols in wireless sensor networks”, Elsevier Ad Hoc Network Journal, Vol. 3, no. 3, pp. 325—349.*

Course Outcomes:

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

1. Understand the concepts, terminologies and challenges in Wireless Sensor Networks
2. Understand the various components of a WSN
3. Investigate the different types of protocols
4. Appraise the software tools for simulation and introduction to programming with Motes etc.
5. Expose to various applications of WSN.

Course Code	**:**	**EE701**
Course Title	**:**	**SOFT SWITCHING POWER CONVERTERS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Objectives: To evaluate various soft switching techniques, Design and control of soft switching converters, Soft switching PWM converters, resonant power converters, applications of soft switched converters in renewable energy, electric vehicle and power supplies.

Prerequisites: Power converts, basic knowledge in power electronics

Evaluation of switching loss in hard switched converters, Introduction to soft switching schemes, Comparison between hard switched and soft switching converters, Resonant switches, zero voltage switching (ZVS), zero current switching (ZCS), zero voltage zero-current switching (ZVS-ZCS), Parameters and selection of semiconductor switches for soft switching.

Concept of resonance, Classification of Quasi-Resonant Switches, Non isolated Zero-Current-Switching Quasi-Resonant Converters, Non isolated Zero-Voltage-Switching Quasi-Resonant Converters, Series-Loaded Resonant Converters, Parallel-Loaded Resonant Converters, Series-parallel resonant converters, isolated high order resonant converters.

PWM Soft switched converter**,** Active clamp power converters with soft switching, design of active clamp ZVS fly back converter, high voltage gains ZVS converters, high voltage gains ZVS/ZCS converters.

Soft switched PWM Full bridge converters, Theoretical Basis of Soft Switching for PWM Full-Bridge Converters, Classification of Soft-Switching PWM Full-Bridge Converters, Zero-Voltage-Switching PWM Full-Bridge Converters, Modulation of the Lagging Leg, Modulation of the Leading Leg, Dual active bridge (DAB) converters and modulation strategy.

Application of resonant and PWM soft switched converters I renewable energy, on –board battery charging, wireless power transfer, power factor correction, DAB converters in solid state transformer.

Text Books:

1. *Robert Erickson, Dragan Maksimovic "Fundamentals of power electronics", Springer publications, 2001.*
2. *Marian K. Kazimierczuk, Dariusz Czarkowski, "Resonant Power Converters", Wiley Publications, Second Edition, 2010.*
3. *Simon S. Ang, Alejandro Oliva, "Power-Switching Converters" CRC Press Publications, 3nd edition, 2010.*
4. *Xinbo Ruan, "Soft-Switching PWM Full-Bridge Converters: Topologies, Control, and Design" Wiley Publications, 2014.*
5. *Ivo Barbi, F. Pottker "Soft commutation Isolated DC/DC Converters" Springer Publications, 2019.*

Course Outcomes:

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

1. Understand various soft switching techniques
2. Select suitable soft switching scheme for different semiconductor switches according to the applications
3. Analysis, design of various soft switched converters

Course Code	**:**	**EE702**
Course Title	**:**	**SOLAR PV SYSTEMS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Objectives: To understand the concepts, operation, MPPT techniques, power conditioning and applications of solar PV systems.

Introduction to solar PV system, history of photovoltaics, photovoltaic effect, photovoltaic cell, equivalent circuit, electrical characteristics, PV terminology, maximum power point tracking.

Partial shading of PV arrays, causes, effect of partial shading on PV power, hot spots, bypass diode, PV characteristics, interconnection schemes, series and parallel connection, total cross tied (TCT), honey comb(HC), bridge linked (BL), reconfiguration techniques, electrical array reconfiguration techniques, Su Do Ku based reconfiguration technique.

Maximum power point tracking algorithm, direct methods, differentiation method, feedback voltage or current method, perturb and observe method, incremental conductance method, parasitic capacitance method, indirect methods, curve fitting method, look up table method, open circuit voltage sensing method, short circuit current sensing method, artificial intelligence techniques, artificial neural network, fuzzy logic, genetic algorithm, algorithm for non-uniform insulation conditions, fibonacci search method, short current pulse method, two stage method.

Power conditioning for PV System, maximum power point tracking, buck converter, boost converter, buck boost converter, cuk converter, SEPIC converter, charge controller, shunt controller, series controller, inverters, inverter operation, power quality standards, grid interconnection techniques.

Application of solar PV and energy storage - standalone systems, roof top system, street lighting systems, PV water pumping systems, grid connected systems, central inverter, string inverter, module inverter, need for energy storage in PV systems, selection of PV battery, battery charging and discharging characteristics, battery life time, battery protection and regulation.

Reference Books:

1. *Chetan Singh Solangi, 'Solar Photovoltaics-Fundamentals, Technologies and Applications', PHI Learning Pvt Ltd, Delhi,2011.*
2. *Van Overstraeton and Metens R.P,. 'Physics, Technology and use of Photovoltaics', Adam Hilger, Bristol, 1996.*
3. *Konrad Mertens, 'Photovoltaics Fundamentals technology and Practice', Wiley publications 2014.*
4. *Chetan Singh Solangi, 'Solar Photovoltaics Technology and Systems', 2013.*

Course Outcomes:

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

1. Appraise the need and possibility of extracting solar energy converting into electrical energy using PV cell.
2. Design and analyze PV array under partial shading conditions.
3. Design and analyze stand alone and electrical grid connected PV system.

Course Code	:	**EE703**
Course Title	:	**E-Vehicle Technology and Mobility**
Number of Credits	:	**3**
Course Type	:	**Elective**

Course objective: This course introduces the fundamental concepts, principles, analysis and design of e-vehicles.

Pre –requisites: Electrical Machines and Power Converters

Introduction to electric vehicles: EV verses gasoline vehicles, vehicle dynamics fundamentals, e-drivetrain, Electric motor, Power electronic in electric vehicles, Regenerative braking.

Battery Technology for EVs: Storage technologies for EV, Battery working principles, Battery losses, Li-ion batteries, Battery pack and battery management system.

Charging Technology of EVs: AC charging - Type 1,2,3, DC charging, Fast charging and its limitations, Smart charging and applications, Vehicle to X(V2X), X2V technology.

Future trends in e-Vehicles: Wireless charging of EV, On-road charging of EV, Battery swap technology, Solar powered EVs, Charging EVs from renewables.

E-mobility: electrification challenges, business, connected mobility and autonomous mobility-case study in Indian Roadmap Perspective, Policy- EVs in infrastructure system, integration of EVs in smart grid, social dimensions of EVs.

Text book(s) and/or required materials:

1. *Iqbal Hussain, "Electric & Hybrid Vehicles – Design Fundamentals", Second Edition, CRC Press, 2011.*
2. *James Larminie, "Electric Vehicle Technology Explained", John Wiley & Sons, 2003.*

Reference Books:

1. *Mehrdad Ehsani, Yimin Gao, Ali Emadi, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals", CRC Press, 2010.*
2. *Sheldon S. Williamson, Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles, Springer, 2013.*
3. *Sandeep Dhameja, "Electric Vehicle Battery Systems", Newnes, 2000 .http://nptel.ac.in/courses/108103009/*
4. *Tariq Muneer and Irene Illescas García, "The automobile, In Electric Vehicles: Prospects and Challenges", Elsevier, 2017.*

Course outcome:
The students will be able to

1. Understand the operation principle of electric vehicles.
2. Choose a suitable motors and analyse different power electronics in EVs.
3. Understand the battery technology.
4. Understand future technology for EVs such as smart charging, wireless charging and solar EVs.
5. Distinguishing between different policy perspectives and innovation in future mobility.

Course Code	:	**EE704**
Course Title	:	**Design of Embedded Controllers for Smart Micro-grid**
Number of Credits	:	**3**
Course Type	:	**Elective**

Course Objectives: To enable the learner to understand the concepts of embedded controllers with its Application to smart grids.

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.

Sensors and Special ICs – Voltage Sensor, Current Sensor, Speed Sensor, RMS calculation IC, Battery Management IC, Opto-couplers and Current amplification transistors.

Real time operating systems(RTOS)–real time kernel– OS tasks–task states– task scheduling– interrupt processing – Embedded Networks –Distributed Embedded Architecture– Hardware and Software Architectures, Networks for embedded systems– I2C, CANBus, Ethernet, Internet, Network– Based design– Design Example: Elevator Controller.

Typical FPGA board qualitative analysis: FPGA IC interfacing with peripherals: ADC, DAC, display (LED, LCD), Communication networks like Ethernet.

Study of a Smart Micro-grid model – Sensors interfacing with FPGA board – Design of Source and Load Controllers – Communication between the controllers – Concepts of Source and Load management.

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. *Herma K., Real Time Systems: Design for Distributed Embedded Applications, Kluwer Academic, 2ndEdition, 2011.*
4. *WilliamHohl, 'ARM Assembly Language, Fundamentals and Techniques', CRC Press, 2009*
5. *Nazzareno Rossetti, "Managing Power Electronics: VLSI and DSP-driven Computing systems:, Wiley-Interscience Publications, 2006.*
6. *Krzysztof Iniewski, "Smart Grid Infrastructure & Networking", Mc-Graw Hill Education (India) Limited, 2012.*

Course Outcomes:

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

1. Understand the architecture of Embedded systems
2. Explore the possible peripherals with the processor
3. Acquire the knowledge of requirements of the real time OS and embedded networks.
4. Appraise the typical use of FPGA as embedded controller
5. Apply the concepts of embedded controllers for smart grid