



M. Tech.

IN

POWER SYSTEMS

CURRICULUM

(For students admitted in 2017-18)



**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 Systems is 64 .

SEMESTER I

Sl. No.	Course Code	Course Title	Credits
1	MA603	Advanced Engineering Mathematics	3
2	EE601	Advanced Power System Analysis	3
3	EE603	Power Conversion Techniques	3
4		ELECTIVE 1	3
5		ELECTIVE 2	3
6		ELECTIVE 3	3
7	EE607	Power Conversion Laboratory	2
Total			20

SEMESTER II

Sl. No.	Course Code	Course Title	Credits
1	EE602	Power System Operation And Control	3
2	EE604	Advanced Power System Protection	3
3	EE606	Power System Stability	3
4		ELECTIVE 4	3
5		ELECTIVE 5	3
6		ELECTIVE 6	3
7	EE608	Power Systems Laboratory	2
Total			20

**SEMESTER III**

Course Code	Course Title	Credits
EE609	PROJECT WORK - PHASE I	12
Total		12

SEMESTER IV

Course Code	Course Title	Credits
EE610	PROJECT WORK - PHASE II	12
Total		12

LIST OF ELECTIVES

Sl. No.	Course Code	Course Title	Credits
1.	EE653	Linear and Non-Linear Systems Theory	3
2.	EE654	Power Electronic Drives	3
3.	EE656	Industrial Control Electronics	3
4.	EE661	Flexible AC Transmission System	3
5.	EE662	High Voltage DC Transmission	3
6.	EE663	Microcontroller Applications in Power Converters	3
7.	EE664	Advanced Digital Signal Processing	3
8.	EE665	Advanced Digital System Design	3
9.	EE667	Analysis And Design Of Artificial Neural Networks	3
10.	EE668	Digital Controllers In Power Electronics Applications	3
11.	EE669	Computer Networking	3
12.	EE670	Electrical Distribution Systems	3



13.	EE671	Fuzzy Systems	3
14.	EE672	Transient Over Voltages In Power Systems	3
15.	EE673	Renewable Power Generation Technologies*	3
16.	EE674	Power System Planning And Reliability	3
17.	EE675	Modeling And Analysis Of Electrical Machines	3
18.	EE676	Power Quality	3
19.	EE677	Power System Restructuring And Pricing	3
20.	EE678	Computer Relaying And Wide Area Measurement Systems	3
21.	EE679	Swarm Intelligent Techniques	3
22.	EE680	Smart Grid Technologies	3
23.	EE681	Electrical Systems In Wind Energy	3
24.	EE683	Embedded Processors And Controllers	3
25.	EE684	Distributed Generation And Micro-Grids*	3
26.	EE685	Control Design Techniques For Power Electronic Systems	3
27.	EE686	Energy Auditing And Management	3
28.	EE687	Electric and Hybrid Vehicles	3
29.	EE688	Principles Of VLSI Design	3
30.	EE695	Digital Control Systems	3
31.	EE696	Power System Automation	3

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



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- 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 – 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	:	EE601
Course Title	:	ADVANCED POWER SYSTEM ANALYSIS
Number of Credits	:	3
Course Type	:	Core

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	:	EE603
Course Title	:	Power Conversion Techniques
Number of Credits	:	3
Course Type	:	Core

Course Objectives:

The aim of this course to present the concepts of typical power electronic circuits: topologies and control. Converter analysis, modeling, design and control of converters will be presented as relevant to different applications. This course also aims to apply the mathematical skills to a number of practical problems.

Prerequisites:

Knowledge on the power semiconductor devices, electronic circuits, circuit theory and mathematics, such as Fourier series analysis and Laplace transform and differential equations are essential.

DC-DC converters - Buck converter, boost converter, buck - boost converter, averaged circuit modeling, input-output equations, ripple calculations, filter design, case studies

DC-AC inverters -Single phase VSI, Three phase VSI, Single phase CSI, Three phase CSI, voltage control and harmonic reduction in inverters-standard PWM techniques, case studies

AC-DC converters- Uncontrolled rectifiers, single and three phase fully controlled and semi controlled converters, continuous current conduction, discontinuous current conduction, Reactive compensation, Harmonic compensation techniques, case studies

AC-AC converters-single phase and three phase circuits employing Phase angle control, on-off control. AC choppers, case studies

Loss calculations and thermal management: Device models for loss calculations, ratings, safe operating areas, data sheets, forward conduction loss, switching losses, heat sink design, snubber design drive and protection circuits, commutation circuits, Soft switching

Reference Books:

1. Ned Mohan, Undeland and Robbin, 'Power Electronics: converters, Application and design', John Wiley and sons. Inc, 3rd Edition, 2002.
2. Rashid M.H., 'Power Electronics Circuits, Devices and Applications', Prentice Hall India, 3rd Edition 2004.
3. Singh M.D., Khanchandani K. B., 'Power Electronics', Tata McGraw-Hill, 2nd Edition, 2008.
4. Umanand L., 'Power Electronics: Essentials & Applications', Wiley India Pvt. Ltd., 2009.
5. Daniel W. Hart, "Power Electronics", Tata McGraw Hill, 2011.

Course Outcomes:

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

1. be able to explain the working of various power electronic converters.
2. analyze and derive the mathematical relations for typical power converters.
3. have ability to design power converters with given specifications.
4. able to use data sheet and suggest suitable control and other associated circuits for the operation of power converters



Course Code	:	EE607
Course Title	:	POWER CONVERSION LABORATORY
Number of Credits	:	2
Course Type	:	Laboratory

Course Objectives: To enable the Power System students to get an insight into the basic Power Electronic Circuits

To simulate, test and analyse the following Power Electronic Circuits:

- 1) Single- Phase and Three- Phase Controlled Rectifier
- 2) Single- Phase Inverter
- 3) Three- Phase Inverter (120° and 180° modes of operation)
- 4) DC – DC Converters
- 5) Phase Controlled Circuits
- 6) DC and AC Circuit Breakers
- 7) Mini Project

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 and circuit breakers
3. Design basic Power Electronic Control Circuits for Power System Applications



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

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	:	Core

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 Padkya 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	:	EE606
Course Title	:	POWER SYSTEM STABILITY
Number of Credits	:	3
Course Type	:	Core

Course Objectives: This course aims to give basic knowledge about the dynamic mechanisms behind angle and voltage stability problems in electric power systems, including physical phenomena and modeling issues.

Prerequisites: Numerical Methods , Electrical Machines, Power System Analysis

Power system stability considerations – definitions-classification of stability - rotor angle and voltage stability - synchronous machine – Modeling - load modeling concepts - modeling of excitation systems - modeling of prime movers.

Transient stability - swing equation-equal area criterion - solution of swing equation- Numerical methods - Euler method-Runge - Kutta method - critical clearing time and angle - effect of excitation system and governors-Multimachine stability – extended equal area criterion - transient energy function approach.

Small signal stability – state space representation – eigen values - modal matrices - small signal stability of single machine infinite bus system – effect of field circuit dynamics - effect of excitation system-small signal stability of multi machine system.

Voltage stability – generation aspects - transmission system aspects – load aspects – PV curve – QV curve – PQ curve – analysis with static loads – loadability limit - sensitivity analysis - continuation power flow analysis - instability mechanisms – examples.

Methods of improving stability – transient stability enhancement – high speed fault clearing – steam turbine fast valving - high speed excitation systems - small signal stability enhancement - power system stabilizers – voltage stability enhancement – reactive power control.

Reference Books:

1. Kundur, P., 'Power System Stability and Control', McGraw-Hill International Editions, 1994.
2. Van Cutsem, T. and Vournas, C., 'Voltage Stability of Electric Power Systems', KluwerAcademic Publishers, 1998.
3. AbhijitChakrabarti, D.P. Kothari, A.K. Mukhopadhyay and Abhinandan De, 'An Introduction to Reactive Power Control and Voltage Stability in Power Transmission Systems', PHI Learning Private Ltd., 2010.
4. R.Ramanujam, 'Power System Dynamics: Analysis and Simulation', PHI Learning Private Ltd., 2009.

Course Outcomes:

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

1. Understand the basic modeling and stability considerations of power system
2. Investigate transient stability issues of single and multiple synchronous machines in power systems
3. Appraise and analyze the small signal stability and the effects of excitation systems on small signal stability
4. Evaluate the various aspects of voltage stability in power systems
5. Interpret and devise different schemes for improving transient stability and voltage stability.



Course Code	:	EE608
Course Title	:	POWER SYSTEMS LABORATORY
Number of Credits	:	2
Course Type	:	Laboratory

Course Objectives: To understand and analyzing different concepts of the power system which includes generation, transmission and distribution along with control and protection system through the hardware setup.

Prerequisites: Power system analysis, transmission and distribution, switch gear and protection.

List of hardware experiments

1. Measurement of A, B, C, D constants of a long transmission line
2. Microprocessor based Static VAR compensator (SVC)
3. Complete protection scheme for generator
4. Study of various faults using D.C. network analyzer
5. Microprocessor based Thyristor controlled series capacitor (TCSC)
6. Operation of microprocessor based numerical over current relay
7. Microprocessor based Power factor controller.
8. Manual power factor controller.
9. Study of power transfer through a short transmission line
10. Study of three zone protection of a numerical distance relay.
11. Study of power flow through HVDC transmission system.

Course Outcomes:

Upon completion of the course students will be able to

1. Practical understanding of different types of electro mechanical and numerical relays.
2. Practical understanding about transmission line fault analysis, power flow and different type of compensations on transmission lines.
3. Prepare laboratory reports that clearly communicate experimental information in a logical and scientific manner.



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

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	:	EE654
Course Title	:	POWER ELECTRONIC DRIVES
Number of Credits	:	3
Course Type	:	Elective

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.

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	:	Elective

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

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

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

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

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

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

Stepper motors – types, operation, control and applications; servo motors- types, operation, control and applications – servo motor controllers – servo amplifiers – linear motor applications-selection of servo motor.

Reference Books:

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

Course Outcomes:

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

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



Course Code	:	EE661
Course Title	:	FLEXIBLE AC TRANSMISSION SYSTEM
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. Kamakshiah, 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	:	EE663
Course Title	:	MICROCONTROLLER APPLICATIONS IN POWER CONVERTERS
Number of Credits	:	3
Course Type	:	Elective

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

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

8051 microcontroller – architecture – addressing modes – I/O ports - instruction sets – simple assembly language programming.

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

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

Analog to Digital Converter module – Instruction set - instruction description – introduction to PIC microcontroller programming – oscillator selection – reset – interrupts – watch dog timer.

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

Reference Books:

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

Course Outcomes:

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

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



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. Proakis 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-Hopfield and Hamming networks- Kohenssen’s network-Boltzmann 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 Manager Interrupts - General Purpose (GP) Timers - Compare Units - Capture Units And Quadrature Enclosed Pulse (QEP) Circuitry - General Event Manager Information

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

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

Reference Books:

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

Course Outcomes:

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

1. 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. Earl Cox, 'The Fuzzy Systems Handbook', AP professional Cambridge, 1999.

Course Outcomes:

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

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



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. Gallagher, 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 This course makes the student

- Objectives:**
- 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 To acquire skills in planning and building reliable power system

Objectivess:

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.

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 of India, 2nd Edition, 2001.
3. Miller, T.J.E., 'Brushless Permanent Magnet and Reluctance Motor Drives', Clarendon Press, 1st Edition, 1989

Course Outcomes:

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

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



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. *Lorin 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

UNIT – I 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.

UNIT – II 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.

UNIT –III 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.

UNIT –IV 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

UNIT –V 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.*

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	:	EE683
Course Title	:	EMBEDDED PROCESSORS AND CONTROLLERS
Number of Credits	:	3
Course Type	:	Elective

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

Prerequisites: Digital Electronics, Microprocessors & Microcontrollers, Computer Architecture

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

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

ARM7TDMI – architecture overview - processor modes – data types – Registers – program status registers – Simple programs

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

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

Reference Books:

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

Course Outcomes:

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

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



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. Irvani, '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	:	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.