FACULTY OF ENGINEERING

SYLLABUS FOR THE B. E. (ELECTRICAL ENGINEERING)

(2012 course)

WITH EFFECT FROM YEAR 2015-2016

SAVITRIBAI PHULE PUNE UNIVERSITY

Savitribai Phule Pune University
B.E. (Electrical Engineering) - 2012 Course
(w.e.f. 2015-2016)
Semester I

Subject code	Subject Title	Teaching Scheme Weekly load in Hrs.			Examination Scheme (Marks)					
		Lecture	Tutorial	PR	Theory: In Semester Exam	Theory: End Semester Exam	PR	OR	TW	Max. Marks
403141	**Power System Operation and Control**	03	--	02	30	70	--	25	25	**150**
403142	**PLC and SCADA Applications**	04	--	02	30	70	50	--	25	**175**
403143	**Elective I**	03	--	02	30	70	--	--	25	**125**
403144	**Elective II**	03	--	--	30	70	--	--	--	**100**
403145	**Control System II**	03	--	02	30	70	--	25	25	**150**
403146	**Project**	--	02	--	--	--	--	50	--	**50**
TOTAL		**16**	**02**	**08**	**150**	**350**	**150**		**100**	**750**

Semester II

Subject code	Subject Title	Teaching Scheme Weekly load in Hrs.			Examination Scheme (Marks)					
		Lecture	Tutorial	PR	Theory: In Semester Exam	Theory: End Semester Exam	PR	OR	TW	Max. Marks
403147	**Switchgear and Protection**	04	--	02	30	70	--	25	50	**175**
403148	**Power Electronic controlled Drives**	04	--	02	30	70	50	--	25	**175**
403149	**Elective III**	03	--	02	30	70	--	25	25	**150**
403150	**Elective IV**	03	--	--	30	70	--	--	--	**100**
403146	**Project**	--	06	--	--	--	--	100	50	**150**
TOTAL		**14**	**06**	**06**	**120**	**280**	**200**		**150**	**750**

Elective I (403143)
- **A)** **Special Purpose Machines**
- **B)** **Power Quality**
- **C)** **Renewable Energy Systems**
- **D)** **Digital Signal Processing**

Elective II (403144)
- **A)** **Restructuring and Deregulation**
- **B)** **Electromagnetic Fields**
- **C)** **EHV AC Transmission**
- **D)** **Introduction to Electrical Transportation Systems**

Elective III (403149)
- **A)** **High Voltage Engineering**
- **B)** **HVDC and FACTS**
- **C)** **Digital Control System**
- **D)** **Intelligent Systems and its Applications in Electrical Engineering**

Elective IV (403150)
- **A)** **Smart Grid**
- **B)** **Robotics and Automation**
- **C)** **Illumination Engineering**
- **D)** **Open Elective*:VLSI Design**

***Proposed Open Elective: The listed open electives or any other Electives that are being taught in the current semester (Term II) under Engineering faculty or individual college and Industry can define new elective with proper syllabus using defined framework of Elective IV and GET IT APPROVED FROM BOARD OF STUDIES ELECTRICAL ENGINEERING AND OTHER NECESSARY STATUTORY SYSTEMS IN THE SAVITRIBAI PHULE PUNE UNIVERSITY WELL IN ADVANCE BEFORE THE COMMENCEMENT OF SEMESTER.**

403141: Power System Operation and Control

Teaching Scheme			Examination Scheme	
Lectures	**03**	**hrs/week**	**In-Sem Assessment**	**30**
Practical	**02**	**hrs/week**	**End-Sem Assessment**	**70**
			Oral:	**25**
			Term Work:	**25**

Prerequisite:

Basics of Power System

Course Objectives:

- To develop ability to analyze and use various methods to improve stability of power systems
- To understand the need for generation and control of reactive power
- To impart knowledge about various advanced controllers such as FACTs controllers with its evolution, principle of operation, circuit diagram and applications
- To illustrate the automatic frequency and voltage control strategies for single and two area case and analyze the effects, knowing the necessity of generation control.
- To understand formulation of unit commitment and economic load dispatch tasks and solve it using optimization techniques
- To illustrate various ways of interchange of power between interconnected utilities and define reliability aspects at all stages of power system.

Unit 01 : Power System Stability: (6 hrs)

Introduction to stability, dynamics of synchronous machine, swing equation, power angle equation and curve, types of power system stability (concepts of steady state, transient, dynamic stability), equal area criterion, applications of equal area criterion (sudden change in mechanical input, effect of clearing time on stability, critical clearing angle, short circuit at one end of line, short circuit away from line ends and reclosure), solution of swing equation by point by point method, methods to improve steady state and transient stability, numerical based on equal area criteria.

Unit 02 : Reactive Power management: (6 hrs)

Necessity of reactive power control, reactive power generation by a synchronous machine, effect of excitation, loading capability curve of a generator, compensation in power system (series and shunt compensation using capacitors and reactors), Problems with Series Compensation, synchronous condenser.

Unit 03 : FACTs Technology: (6 hrs)

Problems of AC transmission system, evolution of FACTs technology, principle of operation, circuit diagram and applications of SVC, TCSC, STATCOM and UPFC.

Unit 04 : Automatic Generation and Control (AGC): (6 hrs)

Concept of AGC, complete block diagram representation of load-frequency control of an isolated power system, steady state and dynamic response, control area concept, two area load frequency control. Schematic and block diagram of alternator voltage regulator scheme.

Unit 05 : Economic Load Dispatch and Unit Commitment: **(6 hrs)**

A) Economic load dispatch: Introduction, revision of cost curve of thermal and hydropower plant, plant scheduling method, equal incremental cost method, method of Lagrange multiplier (neglecting transmission losses), B_{mn} coefficient, economic scheduling of thermal plant considering effect of transmission losses, penalty factor, numerical.

B) Unit commitment: Concept of unit commitment, constraints on unit commitment – spinning reserve, thermal and hydro constraints, methods of unit commitment – priority list and dynamic programming

Unit 06 : Energy Control and Reliability of Power Systems: **(6 hrs)**

A) Energy Control: Interchange of power between interconnected utilities, economy interchange evaluation, interchange evaluation with unit commitment, types of interchange, capacity and diversity interchange, energy banking, emergency power interchange, inadvertent power exchange, power pools.

B) Reliability of Power Systems: Definition of reliability of power system, Hierarchical levels for reliability study, Reliability evaluation of generation system, loss of load probability (LOLP), loss of load expectation (LOLE), Expected Energy Not Supplied (EENS), generation model, load model, risk model, composite system reliability evaluation, Distribution system reliability evaluation for radial and parallel system, customer oriented and energy based reliability indices.

Learning Outcomes:

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

- Identify and analyze the dynamics of power system and suggest means to improve stability of system
- Suggest the appropriate method of reactive power generation and control
- Analyze the generation-load balance in real time operation and its effect on frequency and develop automatic control strategies with mathematical relations.
- Formulate objective functions for optimization tasks such as unit commitment and economic load dispatch and get solution using computational techniques.

List of Experiments: [Perform experiment 1 or 2 and any seven from 3 to 11 using software]

1. To determine Steady state Stability of synchronous motor (performance).
2. To determine Steady state stability of medium transmission line (performance).
3. To plot swing curve by Point by Point method for transient stability analysis.
4. To apply equal area criteria for analysis stability under sudden rise in mechanical power input.
5. To apply equal area criteria for stability analysis under fault condition.
6. To study reactive power compensation using any device.
7. To study Lagrange multiplier technique for economic load dispatch.
8. To develop dynamic programming method for unit commitment.
9. To study load frequency control using approximate and exact model.
10. To study load frequency control with integral control.
11. To study the two area load frequency control.

Industrial Visit: At least one industrial visit should be arranged to Load Dispatch Center / Power Station

Control Room.

Text Books:

1. Abhijit Chakrabarti, Sunita Halder, “Power System Analysis Operation and Control”, Prentice Hall of India.
2. I. J. Nagrath, D. P. Kothari, “Modern Power System Analysis”, 4th Edition, Tata McGraw Hill Publishing Co. Ltd.,
3. P. S. R. Murthy, “Power System Operation & Control”, Tata McGraw Hill Publishing Co. Ltd.
4. P. S. R. Murthy, “Operation & Control in Power System”, B. S. Publication.

References :

1. Allen J. Wood, Bruce F. Wollenberg “Power Generation, Operation, and Control”, Wiley India Edition.
2. “Electrical Power System Handbook”, IEEE Press.
3. Narain G. Hingorani, Laszlo Gyugyi, “Understanding FACTs” IEEE Press.
4. Olle I. Elgerd, “Electrical Energy System Theory”, 2nd Edition, Tata McGraw Hill. Publishing Co. Ltd.
5. Prabha Kundur “ Power system stability and control” Tata McGraw Hill.
6. R. Mohan Mathur, Rajiv K. Varma, “Thyristor based FACTs controller for Electrical transmission system”, John Wiley & Sons Inc.

403142: PLC and SCADA Applications

Teaching Scheme			**Examination Scheme**	
Lectures	**04**	**hrs/week**	**In-Sem Assessment**	**30**
Practical	**02**	**hrs/week**	**End-Sem Assessment**	**70**
			Practical	**50**
			TW	**25**

Prerequisite:

Logic gates operations, Boolean algebra

Course Objectives:

- To understand the generic architecture and constituent components of a Programmable Logic Controller.
- To develop architecture of SCADA explaining each unit in detail.
- To develop a software program using modern engineering tools and technique for PLC and SCADA.
- To apply knowledge gained about PLCs and SCADA systems to identify few real-life industrial applications.

Unit 01: Introduction to PLC (8 hrs)

Role of automation in Industries, benefits of automation, Necessity of PLC, History and evolution of PLC, Definition, types, selection criterion, Overall PLC system, PLC Input and output modules (along with Interfaces), CPU, programmers and monitors, power supplies, Solid state memory , advantages and disadvantages

Unit 02: Programming of PLC (9 hrs)

Programming equipment, Various techniques of programming, Ladder diagram fundamentals, proper construction of ladder diagram, basic components and their symbols in ladder diagram, MCR (master control relay) and control zones, Boolean logic and relay logic

Timer and counter- types along with timing diagrams, shift registers, sequencer function, latch instruction

Arithmetic and logical instruction with various examples

Unit 03: Advance PLC function (8 hrs)

Input ON/OFF switching devices, Input analog devices, Output ON/OFF devices, Output analog devices, programming ON/OFF Inputs to produce ON/OFF outputs.

Analog PLC operation, PID control of continuous processes, simple closed loop systems, problems with simple closed loop systems, closed loop system using Proportional, Integral & Derivative (PID), PLC interface, and Industrial process example.

Unit 04: Applications of PLC (8 hrs)

PLC interface to various circuits : Encoders, transducer and advanced sensors (Thermal, Optical, Magnetic, Electromechanical, Flow, Level sensors)

Measurement of temperature, flow, pressure, force, displacement, speed, level

Developing a ladder logic for Sequencing of motors, Tank level control, ON OFF temperature control, elevator, bottle filling plant, car parking

Motors Controls: AC Motor starter, AC motor overload protection, DC motor controller, Variable speed (Variable Frequency) AC motor Drive.

Unit 05: SCADA Systems: (8 hrs)

Introduction, definitions and history of Supervisory Control and Data Acquisition, typical SCADA system Architecture, Communication requirements, Desirable Properties of SCADA system, features, advantages, disadvantages and applications of SCADA. SCADA Architectures (First generation - Monolithic, Second generation - Distributed, Third generation – Networked Architecture), SCADA systems in operation and control of interconnected power system, Power System Automation (Automatic substation control and power distribution), Petroleum Refining Process, Water Purification System, Chemical Plant.

Unit 06: SCADA Protocols (7 hrs)

Open systems interconnection (OSI) Model, TCP/IP protocol, DNP3 protocol, IEC61850 layered architecture, Control and Information Protocol (CIP), Device Net, Control Net, Ether Net/IP, Flexible Function Block process (FFB), Process Field bus (Profibus). Interfacing of SCADA with PLC.

Learning Outcomes:

Students will be able to

- Develop and explain the working of PLC with the help of a block diagram.
- Develop architecture of SCADA and explain the importance of SCADA in critical infrastructure.
- Execute, debug and test the programs developed for digital and analog operations.
- Reproduce block diagram representation on industrial applications using PLC and SCADA.

List of Experiments:[Instructions if any for conduction of experiments]

Minimum 11 experiments should be conducted. 6 experiments should be on PLC and 5 experiments should be on SCADA.

a) Experiments No. 1 to 5 are compulsory.
b) Any 1 experiment should be conducted from experiment number 6 to 10.
c) Experiments No. 11 to 14 are compulsory.
d) Any 1 experiment should be conducted from experiment number 15 to 18.

1. Interfacing of lamp & button with PLC for ON & OFF operation. Verify all logic gates.

2. Performed delayed operation of lamp by using push button.
3. UP/DOWN counter with RESET instruction.
4. Combination of counter & timer for lamp ON/OFF operation.
5. Set / Reset operation: one push button for ON & other push button for OFF operation.
6. DOL starter & star delta starter operation by using PLC.
7. PLC based temperature sensing using RTD.
8. PLC based thermal ON/OFF control.
9. Interfacing of Encoder with PLC (Incremental/Decremental)
10. PLC based speed, position measurement system.
11. PLC interfaced with SCADA & status read/command transfer operation.
12. Parameter reading of PLC in SCADA.
13. Alarm annunciation using SCADA.
14. Reporting & trending in SCADA system.
15. Tank level control by using SCADA.
16. Temperature monitoring by using SCADA.
17. Speed control of Machine by using SCADA.
18. Pressure control by using SCADA.

Industrial Visit:

Compulsory visit to SCADA and PLC based automation industry.

Text Books:

1. Gary Dunning, "Introduction to Programmable Logic Controllers", Thomson, 2nd Edition
2. John R. Hackworth, Frederick D., Hackworth Jr., "Programmable Logic Controllers Programming Methods and Applications", PHI Publishers
3. John W. Webb, Ronald A. Reis, "Programmable Logic Controllers: Principles and Application", PHI Learning, New Delhi, 5th Edition
4. Ronald L. Krutz, "Securing SCADA System", Wiley Publications.
5. Stuart A Boyer, "SCADA supervisory control and data acquisition", ISA, 4th Revised edition
6. Sunil S. Rao, "Switchgear and Protections", Khanna Publications.
7. L.A. Bryan, E. A. Bryan, "Programmable Controllers Theory and Implementation" Industrial Text Company Publication, Second Edition

Reference books:

1. Batten G. L., "Programmable Controllers", McGraw Hill Inc., Second Edition
2. Bennett Stuart, "Real Time Computer Control", Prentice Hall, 1988
3. Doebelin E. O., "Measurement Systems", McGraw-Hill International Editions, Fourth Edition, 1990
4. Gordan Clark, Deem Reynders, "Practical Modern SCADA Protocols", ELSEVIER
5. Krishna Kant, "Computer Based Industrial Control", PHI
6. M. Chidambaram, "Computer Control of Process", Narosha Publishing
7. P. K. Srivstava, "Programmable Logic Controllers with Applications", BPB Publications
8. Poppovik, Bhatkar, "Distributed Computer Control for Industrial Automation", Dekkar Publications
9. S. K. Singh, "Computer Aided Process Control", PHI
10. Webb J. W, "Programmable Controllers", Merrill Publishing Company, 1988

Elective – I : 403143 : Special Purpose Machines

Teaching Scheme			Examination Scheme	
Lectures	03	hrs/week	In-Sem Assessment	30
Practical	02	hrs/week	End-Sem Assessment	70
			TW	25

Course Objectives:

- To gain knowledge of operation and performance of synchronous reluctance motors.
- To learn operation and performance of stepping motors.
- To understand operation and performance of switched reluctance motors.
- To familiarize with operation and performance of permanent magnet brushless D.C. motors.
- To illustrate operation and performance of permanent magnet synchronous motors.

Unit01: Generalised Machine Theory: (6 hrs)

Energy in singly excited magnetic field systems, determination of magnetic force and torque from energy. Determination of magnetic force and torque from co-energy, Forces and torques in systems with permanent magnets. MMF of distributed winding, Magnetic fields production of EMFs in rotating machines.

Unit 02 : Permanent Magnet Synchronous and brushless D.C. Motor Drives: (6 hrs)

Synchronous machines with PMs, machine configurations. Types of PM synchronous machines Sinusoidal and Trapezoidal. EMF and torque equations Torque speed characteristics Concept of electronic commutation, Comparative analysis of sinusoidal and trapezoidal motor operations. Applications

Unit 03: Control of PMSM: (6 hrs)

abc-αβ and αβ-dq transformations, significance in machine modelling, Mathematical Model of PMSM (Sinusoidal), Basics of Field Oriented Control (FOC), Control Strategies: constant torque angle, unity power factor.

Unit 04: Reluctance Motor : (6 hrs)

Principle of operation and construction of Switch Reluctance motor, Selection of poles and pole arcs , Static and dynamics Torque production, Power flow, effects of saturation, Performance, Torque speed characteristics, Synchronous Reluctance, Constructional features; axial and radial air gap motors; operating principle; reluctance torque; phasor diagram; motor characteristics Introduction to control of Reluctance Drive. Applications.

Unit 05: Stepper Motor: (6 hrs)

Construction and operation of stepper motor, hybrid, Variable Reluctance and Permanent magnet, characteristics of stepper motor, ; Static and dynamics characteristics, theory of torque production, figures of merit; Concepts of lead angles , micro stepping , Applications selection of motor.

Unit 06: Linear Electrical Machines (6 hrs)

Introduction to linear electric machines. Types of linear induction motors, Constructional details of linear induction motor, Operation of linear induction motor. Performance specifications and characteristics Applications

Learning Outcomes:

Students will be able to

- Reproduce principal of operation of PMSM, Stepper motor, SRM, Switch reluctance and linear motors.
- Develop torque speed and performance characteristics of above motors
- Enlist application of these motors
- Demonstrate various control strategies.

Experiments:

Minimum 06 experiments should be conducted out of the list given below:

1. Experimental analysis of PMSM motor drive.
2. Experimental analysis of BLDC (Trapezoidal Motor) Drive.
3. Experimental analysis of Switched Reluctance Motor Drive.
4. Experimental analysis of Synchronous Reluctance Motor Drive.
5. Experimental analysis of Stepper Motor Drive.
6. Laboratory demonstration of Linear Induction Motor.
7. Simulation of PMSM/BLDC drive.
8. Simulation of Switched Reluctance Drive.
9. Software programing for abc-αβ and αβ-dq transformations.

Text Books :

1. K. Venkatratnam, ‘Special Electrical Machines’, University Press
2. A.E. Fitzgerald Charles Kingsley, Stephen Umans, ‘Electric Machinery’, Tata McGraw Hill Publication
3. T.J.E. Miller, ‘Brushless Permanent magnet and Reluctance Motor Drives’ Clarendon Press, Oxford 1989.
4. V. V. Athani, ‘Stepper Motors: Fundamentals, Applications and Design’, New age International, 1997.

Reference Books :

1. R Krishnan, ‘Permanent Magnet Synchronous and Brushless D.C. Motor Drives’ CRC Press.
2. Ion Boldea, ‘Linear Electric Machines, Drives and maglevs’ CRC press
3. Ion Boldea S. Nasar, ‘Linear Electrical Actuators and Generators’, Cambridge University Press.

Elective – I : 403143:Power Quality

Teaching Scheme			Examination Scheme	
Lectures	03	hrs/week	In-Sem Assessment	30
Practical	02	hrs/week	End-Sem Assessment	70
			TW	25

Course Objectives:

- To develop ability to identify various power quality issues
- To Understand relevant IEEE standards
- To illustrate various PQ monitoring techniques and instruments
- To learn and characterize various PQ problems
- To identify different mitigation techniques

Unit 01: Basics of power quality and standards (6 hrs)

Introduction and importance of Power Quality, symptoms of poor power quality. Various power quality issues such as transients, short duration voltage variations, long duration voltage variations, voltage imbalance, voltage fluctuations, voltage flicker and waveform distortion. Relevant power quality standards such as IEEE 1159- 2009 and IEEE 519- 2014. Grounding and power quality issues.

Unit 02: Voltage sag (6 hrs)

Origin of voltage sags and interruptions, voltage sag characteristics- magnitude, duration, phase angle jump, point on wave initiation and recovery, missing voltage. Area of vulnerability, equipment behaviour under voltage sag, ITIC curve, voltage sag monitoring and mitigation techniques.

Unit 03: Transient Over Voltages and Flickers (6 hrs)

Classification of transients, sources of transient over voltages, computer tools for transient analysis, techniques for over voltage protection.
Voltage flickers – sources of flickers, quantifying flickers and mitigation techniques.

Unit 04: Fundamentals of Harmonics (6 hrs)

Harmonic distortion – voltage and current distortion, power system quantities under non sinusoidal condition – active, reactive and apparent power, power factor – displacement and true power factor, harmonic phase sequences and triplen harmonics, harmonic indices, sources of harmonics, effect of harmonic distortion

Unit 05 : Measuring and control of harmonics (6 hrs)

Concept of point of common coupling and harmonic evaluation, principles of controlling harmonics, Harmonic study procedures and computer tools for harmonic analysis, Devices for controlling harmonic distortion design of filters for harmonic reduction.

Unit 06 : Measuring and solving power quality problems **(6 hrs)**

Introduction, power quality measurement devices – harmonic analyzer, transient disturbance analyzer, oscilloscopes, data loggers and chart recorders, true rms meters, power quality measurements, number of test location, test duration, instrument setup and guidelines.

Learning Outcomes:

Students will be able to

1. Characterize power quality events.
2. Reproduce causes of voltage sag and estimate magnitude of voltage sag.
3. Carry out harmonic analysis and calculate total harmonic distortion.
4. Calculate parameters for passive harmonic filter.

List of Experiments:

Minimum 8 experiments are to be performed from the following list:

1. Study of power quality monitor / analyzer
2. Measurement of harmonic distortion of Desktop / computer and allied equipment
3. Measurement of harmonic distortion of CFL or FTL with electronic ballast and magnetic ballast.
4. Harmonic analysis of no load current of a single phase transformer
5. Analysis of performance of three phase induction motor operated with sinusoidal supply and under distorted supply conditions supplied by 3 phase inverter
6. Analysis of performance of single phase transformer operated with sinusoidal supply and under distorted supply conditions supplied by 1 phase inverter.
7. Measurement of sag magnitude and duration by using digital storage oscilloscope
8. Design of passive harmonic filter – computer simulation for power electronic application
9. Design of active harmonic filter – computer simulation for power electronic application
10. Simulation studies of harmonic generation sources such as VFD, SVC, STATCOM and FACTS devices and harmonic measurement (THD) by using MATLAB
11. Power quality audit of institute or department

Text Books:

1. J. Arrillaga, M. R. Watson, S. Chan, "Power System Quality Assessment", John Wiley and Sons
2. M. H. J. Bollen, "Understanding Power Quality Problems, Voltage Sag and Interruptions", New York: IEEE Press, 2000, Series on Power Engineering.
3. R. C. Dugan, Mark F. McGranghan, Surya Santoso, H. Wayne Beaty, "Electrical Power System Quality", 2nd Edition, McGraw Hill Publication.

Reference Books:

1. Enriques Acha, Manuel Madrigal, "Power System Harmonics: Computer Modeling & Analysis", John Wiley and Sons Ltd.
2. Ewald F. Fuchs, Mohammad A. S. Masoum, "Power Quality in Power Systems and Electrical Machines" Elsevier Publication.
3. G. J. Heydt, "Electric Power Quality", Stars in Circle Publications
4. IEEE Std. 519-1992, IEEE recommended practices and requirements for harmonics control in electrical power system.

Elective- I : 403143: Renewable Energy Systems

Teaching Scheme		Examination Scheme	
Lectures :	**03 hrs/week**	**In-Sem Assessment :**	**30**
Practical :	**02 hrs/week**	**End Sem Assessment :**	**70**
		TW	**: 25**

Prerequisite:

Knowledge of basic renewable sources like solar, wind, biogas, fuel cell, Knowledge of conventional grid,

Course Objectives:

- To develop fundamental understanding about Solar Thermal and Solar Photovoltaic systems.
- To provide knowledge about development of Wind Power plant and various operational as well as performance parameter/characteristics.
- To explain the contribution of Biomass Energy System in power generation.
- To teach different Storage systems, Integration and Economics of Renewable Energy System.

Unit 01 : Solar Thermal **(6 hrs)**

Solar radiation at the earth's surface, Solar constant, Spectral distribution, Extraterrestrial Radiation, Solar Terrestrial Radiation, Solar radiation geometry, Computation of $\cos\theta$ for any location having any orientation, Empirical equations for predicting the availability of solar radiation: Monthly average daily and hourly global and diffuse radiation, Beam and Diffuse radiation under cloudless skies, Solar radiation on tilted surfaces : a)Beam radiation, b)Diffuse radiation, c)Reflected radiation, d)Flux on tilted surface.

Instruments for measuring solar radiation, Devices for thermal collection and storage, Thermal applications, designing and Performance analysis of liquid flat plate collector for given heat removal factor and loss coefficient. Introduction to concentrating solar power (CSP) plants using technologies like a) Parabolic troughs b) Linear Fresnel reflector, c) Paraboloid Dish, etc.

Unit 02 : Solar Photovoltaic **(6 hrs)**

Introduction to family of solar film technology, Single c-Si, Poly c-Si PV Cell, Module and Array, Array Design (factors influencing the electrical design of the solar array) : a) Sun Intensity, b)Sun Angle, c) Shadow Effect, d) Temperature Effect, e) Effect of Climate, f) Electrical Load Matching, g) Sun Tracking, Peak Power Point Operation, Electrical characteristics of Silicon PV Cells and Modules, PV System Components, Efficiency of PV system, MPPT of solar system, PV system designing, PV powered water pumping.

Unit 03 : Wind Energy System **(6 hrs)**

Power Contained in Wind, Thermodynamics of Wind Energy, Efficiency Limit for Wind Energy Conversion, Maximum Energy obtained for a Thrust-operated converter (Efficiency limit), Design of Wind Turbine Rotor, Power-Speed Characteristics, Torque-Speed Characteristics, Wind Turbine Control Systems: a) Pitch Angle Control, b) Stall Control, c) Power Electronics Control, d) Yaw Control, Control Strategy, Wind Speed Statistics, Statistical Wind Speed

Distributions, Site and Turbine Selection, Extraction of wind energy and wind turbine power. Introduction to Offshore Wind Energy System and its comparison with Wind Energy System,

Unit 04 : Biomass Energy System (6 hrs)

Biomass Classification, Biomass Resources and their Energy Potential,
Biomass Conversion Technologies: Anaerobic Digestion, Ethanol Fermentation,
Biomass Gasification: Gasifiers, Fluidized Bed Gasifier, Biogas Technologies and their factor affecting Biogas Production,
Biogas Plants: Floating and Fixed Dome type, designing of biogas plant
Power Generation from Municipal Solid Waste (MSW), Land Fill Gas, Liquid Waste.

Unit 05 : Fuel cell and Storage Systems (6 hrs)

a) Fuel Cells: Operating principles of Fuel Cell, Fuel and Oxidant Consumption, Fuel Cell System Characteristics, Introduction to Fuel Cell Technology and its type, application and limits.

b) Storage systems: Hydrogen storage: Hydrogen production, relevant properties, Hydrogen as an Engine Fuel, methods of Hydrogen storage.
Batteries: Introduction to Batteries, Elements of Electro Chemical Cell, Battery classification, Battery Parameters, Factors affecting battery performance.
Introduction to other storage technologies: pump storage, SMES, compressed air storage

Unit 06 : Integration and Economics of Renewable Energy System (6 hrs)

a) Integration of RES with grid, standards. Grid codes
b) Economics of RES: Simple, Initial rate of return, time value, Net present value, Internal rate of return, Life cycle costing, Effect of fuel Escalation, Annualized and levelized cost of energy.

Learning Outcomes:
Students will be able to

- Write theory of sources like solar, wind and also experiments of same.
- Analyze operating conditions like stand alone and grid connected of renewable sources,
- Reproduce different Storage Systems, concept of Integration and Economics of Renewable Energy System

List of Experiments

Minimum 08 experiments should be conducted out of the list given below:
1. To identify and measure the parameters of a Solar PV Module with Series and/or Parallel combination.
2. To plot I-V and P-V characteristics with series and parallel combination of Solar PV Modules for different Insolation and temperature effects.
3. To evaluate effect of Shading and Tilt Angle on I-V and PV characteristics of Solar Module.
4. To estimate effect of sun tracking on energy generation by Solar PV Module.
5. To estimate efficiency of standalone Solar PV Module.
6. To evaluate performance of Solar flat plate collector.
7. To plot characteristics of lead-acid battery for various source and load condition.

8. To analyze effect of blade angles on performance of wind turbine.
9. To evaluate performance of horizontal axis wind turbine.
10. To evaluate performance evolution of vertical axis wind turbine.
11. To study synchronization of wind electric generator.
12. Wind generation analysis using Matlab for variable wind speeds.
13. Field visit to Renewable Energy Sources locations or Manufacturing Industry.
14. To evaluate efficiency of DFIG System (Hardware setup only).

Text Books:

1. S.P. Sukhatme, "Solar Energy", Tata McGraw Hill
2. Mukund R. Patel, "Wind and Power Solar System", CRC Press
3. Tony Burton, Nick Jenkins, David Sharpe, "Wind Energy Hand Book-Second Edition", John Wiley & Sons, Ltd., Publication
4. Godfrey Boyle, "Renewable Energy", Third edition, Oxford University Press
5. Gilbert M. Masters, "Renewable and Efficient Electrical Power Systems", Wiley - IEEE Press, August 2004
6. Chetan Singh Solanki, "Solar Photovoltaics-Fundamentals, Technologies and Applications", PHI Second Edition.
7. H. P. Garg, J. Prakash, "Solar Energy-Fundamentals and Applications", Tata McGraw hill Publishing Co. ltd., First Revised Edition.

Reference books:

1. D.P.Kothari, K.C.Singal, Rakesh Rajan,"Renewable Energy Sources and Emerging Technologies", PHI Second Edition
2. Paul Gipe, "Wind Energy Comes of Age", John Wiley & Sons Inc.
3. Donald L. Klass, "Biomass for Renewable Energy, Fuels, and Chemicals, Elsevier, Academic Press
4. S. Rao, Dr. B. B. Parulekar, "Energy Technology – Non Conventional, Renewable and Conventional", Khanna Publication.
5. Tapan Bhattacharya, "Terrestrial Solar Photovoltaics", Narosa Publishing House.
6. Thomas Ackermann, "Wind Power in Power Systems", Wiley Publications.
7. B T.Nijaguna, "Biogas Technology", New Age International Publishers.

Elective- I : 403143: Digital Signal Processing

Teaching Scheme
Lectures : 03 Hrs/week
Practical : 02 Hrs/week

Examination Scheme
In-Sem Assessment : 30 Marks
End Sem Assessment : 70 Marks
TW : 25 marks

Prerequisite: Knowledge of basic signals and systems

Course Objectives:

- To elaborate Sampling theorem, classification of discrete signals and systems
- To analyze DT signals with Z transform, inverse Z transform and DTFT
- To describe Frequency response of LTI system
- To introduce Digital filters and analyze the response
- To demonstrate DSP Applications in electrical engineering

Unit 01: **Classification of Signals:** **(6 hrs)**
Analog, Discrete-time and Digital, Basic sequences and sequence operations, Discrete-time systems, Properties of D. T. Systems and Classification, Linear Time Invariant Systems, impulse response, linear convolution and its properties, properties of LTI systems: stability, causality, parallel and cascade connection, Linear constant coefficient difference equations, Periodic Sampling, Sampling Theorem, Frequency Domain representation of sampling, reconstruction of a band limited Signal, A to D conversion Process: Sampling, quantization and encoding.

Unit 02: **Z-transform, ROC and its properties:** **(6 hrs)**
Z transform properties: Linearity, time shifting, multiplication by exponential sequence, differentiation, conjugation, time reversal, convolution, initial value theorem, Unilateral Z-transform: , Inverse z transform by inspection, partial fraction, power series expansion and complex inversion, solution of difference equation

Unit 03: Representation of Sequences by Fourier Transform, Symmetry properties of D. T., F. T. theorems: Linearity, time shifting, frequency shifting, time reversal, differentiation, convolution theorem, Frequency response analysis of first and second order system, steady state and transient response **(6 hrs)**

Unit 04: **Sampling the F.T., Fourier representation of finite-duration sequences:** **(6 hrs)**
Sampling theorem in frequency domain. The Discrete Fourier Transform, Relation with z transform Properties of DFT: Linearity, circular shift, duality, symmetry, Circular Convolution, Linear Convolution using DFT, Effective computation of DFT and FFT, DIT FFT, DIF FFT, Inverse DFT using FFT

Unit 05: **Frequency Response of LTI Systems:** **(6 hrs)**
Ideal frequency selective filters, Concept of filtering, specifications of filter, IIR filter design from continuous time filters: Characteristics of Butterworth, and

Cheybyshev, impulse invariant and bilinear transformation techniques, Design examples, Basic structures for IIR Systems: direct form, cascade form

Unit 06: FIR filter design using windows: properties of commonly used windows, Design Examples using rectangular, hamming and hanning windows. Basic Structures for FIR Systems: direct form. Comparison of IIR and FIR Filters **(6 hrs)**
Applications: Measurement of magnitude and phase of voltage, current, power and frequency, power factor correction, harmonic Analysis & measurement, applications to machine control, DSP based protective relaying.

Learning Outcomes:

Student will be able to

- Sample and reconstruct any analog signal
- Find frequency response of LTI system
- Find Fourier Transform of discrete signals
- Design of IIR & FIR filter and implementation of them

List of Experiments:[Total eight experiments are to be performed]
Note: Perform the practical using C language or any other professional software for group A & B

GROUP-A (Any Three)
1. Plotting of discrete time waveforms (a) Sin, (b) Unit Step, (c) Exponential.
2. Find Linear convolution
3. Plot frequency response of given system function (Magnitude & Phase)
4. Verification of Z-transform properties (any two)

GROUP-B (Any Four)
1. Find DFT & IDFT of sequence
2. Find Circular convolution Using DFT IDFT method and linear convolution using Circular convolution.
3 DIT- FFT or DIF-FFT algorithm
4. Design of IIR filter (Butterworth method).
5. Design of FIR filter (window (any one) method).

Group-C (Any one)
1. Study of DSP starter kit and generation of Sine wave.
2. Discrete implementation of FIR Filter using PIC18F/DSP kit.
3. Discrete implementation of IIR Filter using PIC18F/DSP kit.
4. Harmonic analysis of any non sinusoidal signal using DSP.

Text Books:

1. Proakis J., Manolakis D., "Digital signal processing", 3rd Edition, Prentice Hall, ISBN 81- 203-0720-8
2. P. Ramesh Babu, "Digital Signal Processing", 4th Edition Scitech Publication
3. Dr.S. D. Apte,"Digital Signal Processing",2nd Edition Wiley India Pvt. Ltd ISBN: 978-81-265-2142-5
4. W.Rebizant, J.Szafran, A.Wiszniewski, "Digital Signal Processing in Power system Protection and Control", Springer 2011 ISBN 978-0-85729-801-0

Reference books:

1. Mitra S., "Digital Signal Processing: A Computer Based Approach", Tata McGraw-Hill, 1998, ISBN 0-07-044705-5
2. A.V. Oppenheim, R. W. Schafer, J. R. Buck, "Discrete Time Signal Processing", 2nd Edition Prentice Hall, ISBN 978-81-317-0492-9

Elective-II: 403144: Restructuring and Deregulation

Teaching Scheme		**Examination Scheme**	
Lectures	**03 hrs/week**	**In-Sem Assessment**	**30**
		End-Sem Assessment	**70**

Course Objectives:

- To educate students about the process of restructuring of power system
- To familiarize students about the operation of restructured power system
- To teach students pricing of electricity
- To gain knowledge of fundamental concept of congestion management
- To analyze the concept of locational marginal pricing and transmission rights.
- To provide in-depth understanding of operation of deregulated electricity market systems.

Unit 01: Power Sector in India (6 hrs)

Institutional structure before reforms. Roles of various key entities in India. Necessity of Deregulation or Restructuring. RC Act 1998 and Electricity Act 2003 and its implications for Restructuring & Deregulation. Institutional structure during reform. National Energy policy. Introduction to Energy Exchange and trading of Renewable Energy Credits and Carbon Credits.

Unit 02: Power Sector Economics (6 hrs)

Introduction to various concepts such as capital cost, debt and equity, depreciation, fixed and variable costs, working capital, profitability indices etc. Typical cost components of utilities such as return in equity, depreciation, interest and finance charges, O and M expenses etc. Key Indices for assessment of utility performances. Principles of Tariff setting, Phases of Tariff determination, consumer tariff & non-price issues.

Unit 03: Power Sector Regulation (6 hrs)

Regulatory process in India, types and methods of Regulation, cost plus, performance-based regulation, price cap, revenue cap regulation, rate of return regulation, benchmarking or yardstick regulation. Role of regulatory commission. Considerations of socio economic aspects in regulation.

Unit 04: Introduction to Power Sector Restructuring (6 hrs)

Introduction, models based on energy trading or structural models – monopoly, single buyer, wholesale competition, retail competition. Models based on contractual arrangements – pool model, bilateral dispatch, pool and bilateral trades, multilateral trades, ownership models, ISO models. Competition for the market vs competition in the market, International experience with electricity reform – Latin America, Nordic Pool, UK, USA, China and India. California Energy Crisis.

Unit 05: Electricity Markets (6 hrs)

Trading **–** electricity market places, rules that govern electricity markets, peculiarity of electricity as a commodity, various models of trading arrangements – integrated trading model, wheeling trading model, decentralized trading model. Various electricity markets such as spot, day ahead, forward, future options, reserve, ancillary services market. Market operation, settlement process, Market Clearing Price (MCP), Market power, market efficiency. Spot, dynamic and locational pricing.

Unit 06: Transmission Pricing & Transmission Congestion Issues (6 hrs)

Cost components of transmission system, Transmission pricing methods. Cost of transmission services, physical transmission rights. Pricing and related issues. Congestion in power network, reasons for congestion, classification of congestion management, useful definitions. Methods of congestion management, Locational marginal Pricing (LMR), Firm Transmission Right (FTR). Availability based Tariff (ABT) in India.

Learning Outcomes: Student will be able to

- Describe the process of restructuring of power system
- Identify various operation of restructured power system
- Analyze Fundamental concept of congestion management.
- Analyze pricing and transmission rights of Electricity**.**
- Analyze various cost components in Generation, transmission, distribution sector and tariff

Text Books:

1. Lei Lee Lai, " Power System Restructuring and Deregulation" John Wiley and Sons UK, 2001
2. "Know Your Power:, A citizen Primer on the electricity Sector, Prayas Energy Group, Pune

Reference books:

1. Sally Hunt, "Making Competition Work in Electricity", 2002, John Wiley Inc
2. Steven Stoft, " Power System Economics: Designing Markets for Electricity", John Wiley & Sons, 2002
3. Mohammad Shahidehpour, Muwaffaq Alomoush, "Restructured Electrical Power Systems: Operation Trading and Volatility" CRC Press, 06-Jun-2001.
4. Kankar Bhattacharya, Math Bollen, Jaap E. Daalder, "Operation of Restructured Power Systems" Springer US, 2012.
5. H. Lee Willis, Lorrin Philipson, "Understanding Electric Utilities and De-regulation" CRC Press, 31-Oct-2014.
6. Daniel S. Kirschen, Goran Strbac, "Power System Economics" John Wiely & Sons Publication Ltd. August 2006.
7. Geoffrey Rothwell, Tomas Gomez, "Electricity Economics Regulation and Deregulation" A John Wiley & Sons Publication 2003.
8. Mohammad Shahidehpour, Hatim Yamin, Zuyi Li, "Market operations in Electric Power System" A John Wiley & Sons Publication.

Elective-II: 403144: Electromagnetic Fields

Teaching Scheme
Lectures 03 hrs/week

Examination Scheme
In-Sem Assessment 30
End-Sem Assessment 70

Prerequisite: Vector Algebra, Coordinate system, Magnetic field Intensity, Fundamental relations for Electrostatic and Magnetostatic fields

Course Objectives:

- To impart knowledge on the basics of Static Electric and Static Magnetic Field and the associated laws.
- To understand the boundary conditions
- To analyze time varying electric and magnetic fields.
- To understand Maxwell's equation in different form and media.
- To give insight to propagation of EM waves

Unit01: Static Electric Field (6 hrs)

Gradient, Divergence basics, Curl, the vector operator del, Divergence theorem, Coulombs law, Electric field intensity, Point, Line, Surface and Volume charge distributions, Electric flux density, Gauss law and its applications, Gauss divergence theorem, Absolute Electric potential, Potential difference, Calculation of potential differences for different configurations. Electric dipole, Electrostatic Energy and Energy density.

Unit 02: Conductors, Dielectrics and Capacitance (6 hrs)

Current and current density, Continuity of current, Boundary conditions of perfect dielectric materials, Boundary conditions for perfect dielectric materials, Capacitance, Capacitance of a two wire line, Poisson's equation, Laplace's equation, Solution of Laplace and Poisson's equation, Application of Laplace's and Poisson's equations.

Unit 03: Static Magnetic Fields (6 hrs)

Biot -Savart Law, Ampere's Circuital Law, Curl, Stokes theorem, Magnetic flux and magnetic flux density, The Scalar and Vector Magnetic potentials, Derivation of Steady magnetic field Laws.

Unit 04: Magnetic Forces, Materials and Inductance (6 hrs)

Force on a moving charge, Force on a differential current element, Force between differential current elements, Force and torque on a closed circuit, The nature of magnetic materials, Magnetization and permeability, Magnetic boundary conditions, The magnetic circuit, Potential energy and forces on magnetic materials, Inductance and mutual inductances.

Unit 05: Time Varying Fields and Maxwell's Equations **(6 hrs)**

Faraday's law for Electromagnetic induction, Displacement current, Point form of Maxwell's equation, Integral form of Maxwell's equations, Motional Electromotive forces.

Unit 06: Electromagnetic Waves **(6 hrs)**

Derivation of Wave Equation – Uniform Plane Waves – Maxwell's equation in Phasor form – Wave equation in Phasor form – Plane waves in free space and in a homogenous material.

Wave equation for a conducting medium – Plane waves in lossy dielectrics –Propagation in good conductors – Skin effect. Poynting's theorem.

Outcomes:

Students will be able to:

- Interpret Electric and Magnetic Field with the help of associated laws
- Solve electromagnetic problems with the help of mathematical tools
- Solve simple electrostatic and magnetic boundary conditions
- Analyze and solve electromagnetic problems using Maxwell's equations

Text Books:

1. W H.Hayt & J A Buck: "Engineering Electromagnetics" TATA McGraw-Hill, 7th Edition 2007.
2. S. P. Ghosh, Lipika Datta, "Electromagnetic Field Theory" McGraw-Hill Education India Private Limited.
3. Matthew N.O. Sadiku, "Principles of Electromagnetics", Oxford University Press Inc, New Delhi, 2009.
4. Edward C. Jordan and Keith G. Balmain, "Electromagnetic waves and Radiating Systems", PHI, 2nd Edition.

Reference books:

1. Ashutosh Pramanik, " Electromagnetism", PHI Learning Private Limited, 2014
2. Kraus Fleisch, "Electromagnetics with applications", McGraw Hill, 5th Edition.
3. Bhag Singh Guru, Huseyin R. Hiziroglu, "Electromagnetic Field Theory Fundamentals", Cambridge University Press, 2nd Edition.

Elective-II: 403144: EHV AC Transmission

Teaching Scheme
Lectures 03 hrs/week

Examination Scheme
In-Sem Assessment 30
End-Sem Assessment 70

Course Objectives:-

- To understand the need of EHV and UHV systems.
- To describe the impact of such voltage levels on the environment
- To know problems encountered with EHV and UHV transmissions
- To know methods of governance on the line conductor design, line height and phase etc.

Unit 01 EHV ac transmission lines (6 hrs)

Need for EHV transmission lines, Power handling capacity and line loss, Examples on giant power pools and number of lines, Mechanical considerations in line performance, Vibrations Travelling wave equations, transmission reflection attenuation and distortion of travelling waves, transmission and reflection coefficients and examples**.**

Unit 02 Calculation of line and ground parameters (6 hrs)

Resistance of conductors, effect of temperature on overhead conductors, temperature rise of conductors and current carrying capacity, Properties of bundled conductors, Inductance of current carrying single conductor, Inductance of EHV line configurations, Line capacitance calculations. Sequence inductances and capacitances, Diagonalization.

Unit 03 Voltage gradient of conductors (6 hrs)

Electrostatic Field of a point charge and its properties, Field of sphere gap, Field of line charges and their properties, Corona inception gradients, charge potential relations for multi-conductor lines, Maximum charge condition on three phase line.

Surface voltage gradient on conductors-single conductor, two conductors and multi-conductor bundle, Maximum surface voltage gradient, Mangoldt formula, design of cylindrical cage for corona gradients

Unit 04 : Electrostatic and magnetic fields of EHV lines (6 hrs)

Electric shock and threshold currents, Effects of high electrostatic fields on humans, animals and plants, Calculation of electrostatic field of single circuit of three phase line, Profile of electrostatic field of line at ground level.

Electrostatic induction on un-energized circuit of a double circuit line. Insulated ground wire and induced voltage in insulated ground wires.

Magnetic field calculation of horizontal configuration of single circuit of three phase lines,

Effects of power frequency magnetic fields on human health.

Unit 05: Corona and its effects **(6 hrs)**

Corona formation, corona inception voltage, visual corona voltage, critical field for corona inception and for visual corona under standard operating condition and conditions other than standard operating conditions.

Power loss due to corona, corona loss formulae, corona current waveform, charge-voltage diagram and corona loss, increase in effective radius of conductor and coupling factors, attenuation of travelling waves due to corona loss. Audible noise operation and characteristics limits for audible noise, AN measurement and meters, microphone, weighting networks. Formulae for audible noise and use in design, relation between single phase and three phase AN levels.

Design of cylindrical cages for corona experiments-single conductor concentric with cylinder, single conductor with eccentricity.

Unit 06: **(6 hrs)**

A) Design of EHV lines

Design of EHV lines based upon steady state limits and transient over voltages, design factors under state. Design examples: steady state limits.

Line insulation design based on transient over voltages

B) Extra high voltage cable transmission

Classification of cables, Typical insulation thickness for ehv cables, Properties of cable insulation materials.

Learning outcomes:-

Student will be able to

- Highlight need for EHV ac transmission.
- Calculate line and ground parameters.
- Enlist problems encountered in EHV transmission.
- Express issues related to UHV transmission discussed.

Text books:-

1) Rakoshdas Begamudre “Extra high voltage transmission”, New Age International publishers.

Reference books:-

1) S. Rao , “EHV AC and DC Transmission” Khanna publications.

Elective-II: 403144: Introduction to Electrical Transportation Systems

Teaching Scheme		**Examination Scheme**	
Lectures	**03 hrs/week**	**In-Sem Assessment**	**30**
		End-Sem Assessment	**70**

Prerequisite:-

Conversion of electric energy, DC and AC circuit analysis, power electronic conversion, electrical motors, Battery.

Course Objectives:-

- To make students understand the importance and various modes of electric transportation systems such as electric traction, hybrid vehicle and elevators etc.
- To differentiate various source of energy used in transportation and their performance characteristics.
- To impart knowledge about different power and energy converters.
- To classify the different controls used in electric vehicles.
- To demonstrate the knowledge about electric cars and elevators.

Unit 01: General Review of Transportation **(6 hrs)**

Need and importance of mobility, various modes of transportation, evolution of transportation system, Horse carriages to steam engines to internal combustion engines to electric vehicles, advantages and disadvantages of electric mobility, various application of electric mobility such as electrical traction, hybrid electric and electric vehicles, elevators, personal mobility and special applications such as wheel chairs, future concepts.

Unit 02: EV- Basic Building Blocks **(6 hrs)**

Various sources of energy used in transportation and their characteristics, Conventional vehicle power transmission systems. Energy conversions module integrations and their operation. Different types of Batteries & their operation. Types of batteries, their characteristics, charging and discharging of batteries, round trip efficiency, ability to deliver instantaneous power, load cycle and its effect on battery performance, environmental impact of batteries, power quality issues related to charging of batteries. Different load characteristics (Specifically road characteristics)

Unit 03: Power module & Energy converters **(6 hrs)**

Need for power converters, basic power electronic blocks, AC/DC, DC/DC, DC/AC modules.
Types of mechanical drives, conversion of electrical energy into mechanical energy, characteristics of various types of drives, BLDC machines, AC machines, DC machines, mechanical drive / power train

Unit 04: Control system and instrumentation **(6 hrs)**

Function of instrumentation and control system, speed control, acceleration characteristics, mechanical steering versus electric steering, motion control, driverless vehicles, road safety and traffic control and monitoring, emerging trends

Unit 05: **(6 hrs)**

Electric cars

Emerging trend, typical power train architecture, hybrid cars, acceleration and speed characteristics,

Traction

Introduction to Modern AC traction for high speed rail application, their control and performance under different operating conditions. Comparison of AC/DC traction.

Unit 06 : Elevators **(6 hrs)**

Load characteristics of elevator systems, Introduction to control schemes in elevators with new power-electronics controlled drives, considerations for energy efficient systems.
Special vehicles, basic concepts and emerging trend

Course Outcomes:- Students will be able to

- Select between alternative modes for electric transportation system.
- Explain various types of energy storage devices and their impact on electrified transportation.
- Explain various power and energy converters in transportation system.
- Analyze different control systems used in electric vehicles.
- Describe different characteristics of electric car and elevators.

Text Books:

1. James Larminie and John Lowry, "Electrical Vehicle" John Wiley & Sons, 2012.
2. Mark Warner, "The Electric Vehicle Conversion handbook" –HP Books, 2011.
3. Iqbal Husain, "Electric & Hybrid Vehicles-Design Fundamentals", Second edition, CRC press
4. D. A. J. Rand, R. Woods R. M. Dell, "Batteries for Electric Vehicles", New York, John Wiley and Sons.

Reference Books:

1. Mehrdad Ehsani, Yimin Gao and Ali Emadi, "Modern Electrical Hybrid Electric and Fuel Cell Vehicles: Fundamental, Theory and Design", CRC Press, 2009.
2. Burch Edward P., "Electric Traction for Railway Trains" McGraw Hill, 1911.
3. H.Partab, "Modern Electric Traction"–Dhanpat Rai & Sons, 1973.
4. Barney, George C., "Elevators Technology" international Association of Elevator Engineers by Ellis Harwood, 1986.

403145: Control System - II

Teaching Scheme			**Examination Scheme**	
Lectures:	**03**	**hrs/week**	**In-Sem Assessment**	**30**
Practical:	**02**	**hrs/week**	**End-Sem Assessment**	**70**
			Oral :	**25**
			TW:	**25**

Course Objectives:

- To learn the concept of compensation and to realize compensator for a system using active and passive elements.
- To understand the concept of state and to be able to represent a system in the state space format and to solve the state equation and familiarize with STM and its properties.
- To design a control system using state space techniques including state feedback control and full order observer.
- To familiarize with various nonlinearities and their behaviour observed in physical system and to understand the Describing function method and phase plane method.
- To understand the basic digital control scheme, the concept of sampling and reconstruction. To be able to analyze and design a digital control system including realization of digital controllers.

Unit 01: Compensation Technique **(6hrs)**

Approaches and preliminary consideration. Design of Linear Control System, Common compensating network, Transfer function of Lag, Lead and Simple lag-lead network. Design using Bode diagram. Physical realization of compensators using active and passive elements.Tachometer feedback compensation

Unit 02 : Introduction to state space analysis **(6 hrs)**

Important definitions – state, state variable, state vector, state space, state equation, output equation. State space representation for electrical network, n^{th} order differential equation, and transfer function. Conversion of transfer function to state model and vice versa. Concept of diagonalization, eigen values, eigenvectors, diagonalization of system matrices with distinct and repeated eigen values, Vander Monde matrix.

Solution of homogeneous and non-homogeneous state equation in standard form, state transition matrix, its properties, Evaluation of STM using Laplace transform method and infinite series method.

Unit 03: Design of Control System Using State Space Technique: **(6 hrs)**

Concept of controllability and observability, controllability and observability Tests, condition for controllability and observability from the system matrices in canonical form, Jordan canonical form, effect of pole zero cancellation on the controllability and observability of the system, duality property. Pole placement design by state variable feedback. Necessity of an observer, design of full order observer.

Unit 04 : Non linear Control System Analysis **(6 hrs)**

Introduction, classification, common type of non-linearities observed in physical systems, peculiar behavior of nonlinear system- Spurious (subharmonics) response, jump resonance, limit cycle, amplitude as function of frequency oscillation, non linear spring mass system, sub harmonic oscillation, asynchronous quenching, frequency entrainment etc.

Analysis of NLCs using phase plane and describing methods for Ideal Relay

Unit 05: Digital Control System **(6 hrs)**

Introduction, Configuration of the basic digital control scheme. Advantages and limitations of digital control; data conversion and quantization, Sampling & Reconstruction processes, Shannon's Sampling theorem, practical aspects of choice of sampling rate. Zero order hold (ZOH) and it's transfer function, Review of z-transform, difference equations and solution using z transform method.

Unit 06 : Analysis and Design of Digital Control System **(6 hrs)**

Pulse transfer function and z transfer function, General procedure for obtaining Pulse-transfer-function, pulse transfer function of ZOH, sampled data closed loop systems, characteristic equation, causality and physical realizability of discrete data system, realization of digital controller by digital programming, direct digital programming, cascade digital programming, parallel digital programming, Digital PID controller.

Learning outcomes:

Students will able to

- Design and realize a compensator for a physical system,
- Represent a physical system in state space format and analyze the same and to realize a controller using state space technique.
- Analyze understand the various nonlinearities in a physical system.
- Realize digital control schemes.

Experiments:

Set-A: (Compulsory)

1. Op-amp based realization of highly underdamped second order plant. Find out frequency response of the system experimentally
2. Design a lead/lag compensator for given specifications for the plant in Experiment1 using MATLAB.
3. Realize the compensator designed in experiment 2 using op-amp circuits and find out frequency response of the plant and the compensator in closed loop and verify step and frequency response.

Set B: (Any five)

1) Check for observability and Controllability in MATLAB.
2) Verify State feedback control using pole placement.
3) Convert a continuous time system into digital control system and check response using software.
4) Design State observer and validate it by software.
5) Software programming for determination of state space representation for given transfer function and vice-versa
6) Software programming for determination of STM.
7) Study of non linearities using OPAMPs and verification of those by software.
8) Implementation of digital PID controller for physical system.
9) Effect of sampling and verification of sampling theorem.

Text Books:

1. J. Nagrath, M. Gopal "Control System Engineering", 5th Edition. New Age International Publishers
2. Benjamin C. Kuo, "Automatic Control Engineering", Prentice Hall of India Pvt. Ltd.
3. Benjamin C. Kuo "Digital Control System", Prentice Hall of India Pvt. Ltd.

Reference Books:

1. K. Ogata, "Modern Control Engineering", Prentice Hall of India Pvt. Ltd.
2. M. Gopal, "Digital Control and State Variable Methods", Tata McGraw-Hill.
3. M. N. Bandyopadhyay, "Control Engineering – Theory and Practice", Prentice Hall of India Ltd. Delhi.

403146: Project

Teaching Scheme
Tutorial 2 hrs/Week

Examination Scheme
Oral : 50

The student shall take up a project in the field closely related to Electrical Engineering. An individual can undertake project . Preferably, a group of 3 students should be formed for project work.

The project work should be based on the knowledge acquired by the student during the graduation and preferably it should meet and contribute towards the needs of the society. The project aims to provide an opportunity of designing and building complete system or subsystems based on area where the student likes to acquire specialized skills.

Project work in this semester is an integral part of the project work. In this, the student shall complete the partial work of the project which will consists of problem statement, literature review, project overview and scheme of implementation. As a part of the progress report of project work, the candidate shall deliver a presentation on the advancement in Technology pertaining to the selected project topic.

Guidelines for VIIth Semester for Project work

1. To identify the problems in industry and society.
2. Perform Literature survey on the specific chosen topic through research papers, Journals, books etc. and market survey if required.
3. To narrow down the area taking into consideration his/her strength and interest. The nature of project can be analytical, simulation, experimental, design and validation.
4. To define problem, objectives, scope and it's outcomes.
5. To design scheme of implementation of project.
6. Data collection, simulation, design, hardware if any need to be completed.
7. Presentation based on partially completed work.
8. Submission of report based on the work carried out.

403147: Switchgear and Protection

Teaching Scheme			**Examination Scheme**	
Lectures:	**04**	**hrs/week**	**In-Sem Assessment**	**30**
Practical:	**02**	**hrs/week**	**End-Sem Assessment**	**70**
			Oral :	**25**
			TW:	**50**

Prerequisite:

1. Different types of faults in power system
2. Various switchgears and their use in substation
3. Principle and working of rotating machines and transformer with vector groups

Course Objectives:

- To elaborate construction and working principle of different types of HVCBs
- To describe the need of protective Relaying and operating principles of different types of relays.
- Study different type of faults in transformer, alternator and various protective schemes related to them.
- Learn transmission line protection schemes, and characteristics of different types of distance relays

Unit 01 : Fundamentals of protective relaying (8 hrs)

Need for protective system, nature & causes of fault, types of faults, effects of faults, evolution of protective relaying, classification of relays, zones of protection, primary and backup protection, essential qualities of protective relaying. Trip circuit of circuit breaker, zone of protection. Various basic operating principles of protection- over current, (current graded & time graded),directional over current, differential, distance, induction type relay, torque equation in induction type relay, current and time setting in induction relay, Numericals on TSM, PSM and operating time of relay

Unit 02: Fundamentals of arc interruption: (8 hrs)

Ionization of gases, deionization, Electric arc formation , Current interruption in AC circuit breaker, high & low resistance principles, arc interruption theories, arc voltage, recovery voltage, derivation and definition of restriking voltage and RRRV, current chopping, interruption of capacitive current, resistance switching, Numerical on RRRV, current chopping and resistance switching.

Unit 03 : Circuit Breaker (7 hrs)

Different ratings of circuit breaker (like rated voltage, rated current, rated frequency, rated breaking capacity – symmetrical and unsymmetrical breaking, making capacity, rated interrupting duties, rated operating sequence, short time rating). Classification of high voltage circuit breaker. Working and constructional features of ACB, SF_6 VCB- advantages, disadvantages and applications. Auto reclosing. .

Unit 04:

A) Protection against overvoltage due to lightning: (8 hrs)

Overvoltage, causes of overvoltage, Lightning phenomenon, wave shape of lightning stroke, direct & indirect strokes, protection of overhead transmission lines from direct lightning strokes, Lightning arresters, rod gap type, horn gap type, Thyrite type, Metal oxide (ZnO) type lightning arrester.

B) Static & Digital Relaying

Overview of Static relay, block diagram, operating principal, merits & demerits of static relay. Numerical Relays :-Introduction, Block diagram of numerical relay, Sampling theorem, Anti – Aliasing Filter, Block diagram of PMU

Unit 05: (9 hrs)

A) Transformer Protection – Types of faults in transformer. Percentage differential protection in transformers, Restricted E/F protection. Incipient faults, Buchholz relay. protection against over fluxing. Protection against inrush current,

B) Alternator Protection – Various faults in Alternator, abnormal operating conditions- stator faults, longitudinal percentage differential scheme and transverse percentage differential scheme. Rotor faults- abnormal operating conditions, inter turn fault, unbalance loading, over speeding, loss of excitation, protection against loss of excitation using offset Mho relay, loss of prime mover.

C) 3 Phase Induction Motor Protection- Abnormal conditions & causes of failures in 3 phase Induction motor, single phasing protection, Overload protection, Short circuit protection.

UNIT-06: (8 hrs)

A) **Bus bar Protection:** Differential protection of bus bars. Selection of C.T. ratios for bus bar protection. High impedance differential relay.

B) Transmission line: over current protection for feeder using directional &non-directional overcurrent relays, Introduction to distance protection, impedance relay, reactance relay, mho relay & Quadrilateral Relays, Introduction to PLCC, block diagram, advantages, disadvantages, three stepped distance protection, Effect of arc resistance, and power swing on performance of distance relay. Realisation of distance relays (impedance, reactance and mho relay) using numerical relaying algorithm (flowchart, block diagram), Introduction to Wide Area Measurement (WAM) system.

Learning Outcomes:

Student will be able to

- Describe arc interruption methods in circuit breaker.

- Derive expression for restriking voltage and RRRV in circuit breaker
- Explain Construction, and working of different high voltage circuit breakers such as ABCB, SF_6 CB, and VCB.
- Classify and Describe different type of relays such as over current relay, Reverse power relay, directional over current relay, Differential relay, Distance relay, Static relay and numerical relay
- Describe various protection schemes used for transformer, alternator and busbar
- Describe transmission line protection schemes.

List of Experiments:

Minimum **8 Experiments** to be performed from the following list:

3. Study of switchgear testing kit.
4. Study of Fuse, MCB & their testing
5. Study and testing of contactors
6. Study and testing of MCCB
7. Study and testing of ACB
8. Study and testing of thermal overload relay for Induction Motor protection
9. Study and plotting Characteristics of IDMT type Induction over current relay
10. Study and plotting Characteristics of digital over current relay
11. Percentage differential protection of transformer
12. Protection of alternator
13. Protection of Transmission line using Impedance relay
14. Study of various LT switchgears like RCCB, timers

Industrial Visit:

Report on industrial visit to switchgear training centre /or switchgear/relay manufacturing unit/ or 220 kV substation visit.

Text Books:

1. S. Rao, “Switchgear Protection & Power Systems”, Khanna Publications
2. Y. G. Paithankar, S. R. Bhide, “Fundamentals of Power System Protection”, Prentice Hall of India
3. Bhavesh Bhalja, R.P. Maheshwari, N.G. Chothani,” Protection and Switchgear”, Oxford University Press, 2011 Edition.

Reference Books:

1. Badri Ram, D. N. Vishwakarma, “Power System Protection & Switchgear”, Tata McGraw Hill Publishing Co. Ltd.
2. J. Lewis Blackburn , Thomas J. Domin, “Protective Relaying: Principles and Applications”, Fourth Edition, CRC Press.
3. Prof. Dr S.A. Soman, IIT Mumbai , A Web course on “Digital Protection of power System” http://www.cdeep.iitb.ac.in/nptel/Electrical%20Engineering/Power%20System%20Protection/Course_home_L27.html
4. A.G. Phadke and J.S. Thorp , Computer relaying for Power System, Research Studies Press LTD, England.(John Willy & Sons Inc New York)
5. Crussel Mason, “The Art and Science of Protective Relaying”, Wiley Eastern Limited.

403148: Power Electronic Controlled Drives

Teaching Scheme		**Examination Scheme**	
Lectures	**04 hrs/week**	**In-Sem Assessment**	**30**
Practical	**02 hrs/week**	**End-Sem Assessment**	**70**
		Practical	**50**
		TW	**25**

Prerequisites:

1. Construction, working and characteristic of different electrical motors
2. Power Electronic Applications such as converter, inverter, chopper etc.
3. Basic concept of control system

Course Objectives:

- To understand the stable steady-state operation and transient dynamics of a motor-load system.
- To study and analyze the operation of the converter, chopper fed dc drive.
- To study and understand the operation of both classical and modern induction motor drives.
- To study and analyze the operation of PMSM and BLDC drives.
- To analyze and design the current and speed controllers for different drives

Unit 01: Electrical Drives (8 hrs)

Definition, Advantages of electrical drives, Components of Electric drive system, Selection Factors, Types of Electrical Drives (DC & AC). Motor-Load Dynamics, Speed Torque conventions and multi quadrant operation, Equivalent values of drive parameters. Load Torque Components, Nature and classification of Load Torques, Constant Torque and Constant Power operation of a Drive. Steady state stability, Load equalization by using flywheel.

Unit 02: DC Motor Drives (8 hrs)

Starting and braking methods, characteristics of DC Motors: Rheostatic, Plugging, and Regenerative.

Single phase and three phases fully controlled converter drives and performance of converter fed separately excited DC Motor for starting and speed control operations. Chopper controlled drives for separately excited and series DC Motor operations. Closed loop speed control of DC motor below and above base speed.

Unit 03: Induction Motor Drives-I (8 hrs)

DC Dynamic Braking, Plugging, Regenerative Braking, AC Rheostatic braking, motor braking methods using static devices. Closed loop control of drives: current limit control, torque control and speed control.

Thyristorised stator voltage control (using ac regulators, for fixed frequency variable voltage control), V/f control, voltage source inverter (VSI) control, Steady State Analysis

Unit 04: **Induction Motor Drives-II** **(8 hrs)**

Current source inverter (CSI) control-open and closed loop, Regenerative braking and multi quadrant operation of Induction motor drives, relative merits and demerits of VSI and CSI for induction motor drives. Principle of vector control, Vector control of induction motor, Commutator less DC Motor (How Induction Motor is converted to Characteristics of DC Motor),AC Servo Drives.

Unit 05: **Special Machine Drives** **(8 hrs)**

1. **Permanent Magnet Synchronous Motor Drive**: vector control of PM Synchronous Motor (PMSM), Control Strategies: constant torque angle control, unity power factor control, Speed controller design
2. **Permanent Magnet Brushless DC Motor Drive:** Half Wave drives, Sensorless control, Design of current and speed controller

Unit 06: **(8 hrs)**

A)Drive Selection: Selection criteria of motors, motor duties, inverter duty motors. Load diagram, Heating and cooling, Thermal Resistance, determination of HP rating of motor based on duty cycle

B)Industrial Applications: Process/operation—Requirements of load—Suitable Drive—Advantages in following applications: 1)Rolling mills 2)Machine tools 3)Textile mills 4)Sugar Mills 5) Centrifuged Pump, 6) Traction drives 7) Aeronautic applications 8) Electric and Hybrid Vehicle 9) Solar Pumps

Learning Outcomes:

On successful completion of this course students will be able to:

- Analyze the operation of the converter, chopper fed dc drive.
- Analyze the operation of both classical and modern induction motor drives.
- Design the current and speed controllers for a closed loop solid-state d.c motor drive
- Select the drives for any particular application

List of Experiments: Minimum eight experiments are to be performed out of the list mentioned as below:
GROUP A: Any THREE Experiments (Hardware)

1. Study of Electrical braking of D.C. Shunt motor (Rheostatic, Plugging).
2. Study speed control characteristics of single phase fully converter fed separately excited D.C. motor
3. Study speed control characteristics of three phase fully converter fed separately excited D.C. motor
4. Study of Chopper fed D.C. series/separately motor speed control characteristics.
5. Study of control characteristic of BLDC drive

GROUP B: Any THREE Experiments (Hardware)

1. Study of electrical braking of 3 phases Induction Motor (DC Dynamic Braking, Plugging).
2. Study of VSI fed 3 phase Induction motor (using V/f control PWM inverter) speed control characteristics.

3. Study of Solid state stator voltage control of 3 phase Induction motor (Using AC voltage Regulator).
4. Study of VSI fed PMSM control characteristics.
5. Study of constant torque and constant power characteristic of induction motor.

GROUP C: Any TWO Experiments (Software)

1. Simulation of starting characteristics of D.C. / 3 phase Induction motor.
2. Study of Closed loop speed control of separately excited D.C. motor/ Induction Motor.
3. Simulation of an electric drive system for steady state and transient analysis.
4. Simulation/programming of controller design of PMSM/BLDC

Industrial Visit:

Minimum one industrial visit must be organized for drives application in industry such as railways, sugar mill, machine shop, textile mill, paper mill etc.

Text Books:

1. G. K. Dubey, “Fundamentals of Electric Drives”, 2nd Edition, Narosa Publishing House
2. N. K. De, P. K. Sen, “Electric Drives”, Prentice Hall of India Eastern Economy Edition
3. S. K. Pillai, “Analysis of Thyristor Power Conditioned Motors”, University Press
4. R. Krishnan, “Electric Motor Drives – Modeling Analysis and Control”, PHI India

Reference books:

1. B. K. Bose, “Modern Power Electronics and AC Drives”, Pearson Education
2. Malcolm Barnes, “Practical Variable Speed Drives and Power Electronics”, Elsevier Newnes Publications
3. V. Subrahmanyam, “Electric Drives: Concepts & Application”, Tata Mc-Graw Hill (An imprint of Elsevier)
4. M.D. Singh and Khanchandani “Power Electronics”, Tata Mc-Graw Hill
5. Austin Huges, “Electrical motor and drives: Fundamental, types and applications”, Heinemann Newnes, London
6. G.K. Dubey, “Power Semiconductor controlled drives”, PHI publication

Elective –III : 403149: High Voltage Engineering

Teaching Scheme			Examination Scheme	
Lectures	**03**	**hrs/week**	**In-Sem Assessment**	**30**
Practical	**02**	**hrs/week**	**End-Sem Assessment**	**70**
			Oral :	**25**
			TW:	**25**

Course Objectives:

- To make students able to explain the various breakdown processes in solid, liquid and gaseous materials and describe Lightning phenomenon, natural cause of overvoltage in detail with formation of charge in clouds.
- To provide sound knowledge of Testing, Generation & measurement methods of DC, AC and impulse voltages and current.
- To develop ability to carry out various testing procedures as per IS in laboratory with knowledge of earthing, safety and shielding of HV laboratory.

Unit 01: **Breakdown in Gases:** **(6 hrs)**

Ionization process in gas, Townsend's Theory, current growth equation in presence of primary and secondary ionization processes, Townsend's breakdown criterion, primary and secondary ionization coefficients, limitations of Townsend's theory, Streamer mechanism of breakdown, Paschen's Law and its limitations, Corona discharges for point plane electrode combination with positive and negative pulse application, time lag for and factors on which time lag depends. (Numerical on Townsend's theory and Paschen's law).

Unit 02: **(6 hrs)**

1. **Breakdown in Liquid Dielectrics:** Pure and commercial liquids, Different breakdown theories: Breakdown in Pure liquid and breakdown in commercial liquids: Suspended Particle theory, Cavitations and bubble theory, Thermal mechanism of breakdown and Stressed Oil volume theory.
2. **Breakdown in Solid Dielectrics:** Intrinsic breakdown: electronic breakdown, avalanche or streamer breakdown, electromechanical breakdown, thermal breakdown, treeing and tracking phenomenon, Chemical and electrochemical breakdown, Partial discharge(Internal discharge),Composite dielectric material, Properties of composite dielectrics, breakdown in composite dielectrics.
   (Numerical on theories of liquid and solid dielectric materials)

Unit 03: **Lightning and Switching Over Voltages:** **(6 hrs)**

Causes of over voltages, lightning phenomenon, Different types of lightening strokes and mechanisms of lightening strokes, Charge separation theories, Wilson theory, Simpson theory, Reynolds and Mason theory, Over voltage due to switching surges and methods to minimize switching surges. Statistical approach of insulation coordination

Unit 04: **Generation of High Voltages and Current:** **(6 hrs)**

a) Generation of high ac voltages-Cascading of transformers, series and parallel resonance system, Tesla coil

b) Generation of impulse voltages and current-Impulse voltage definition, wave front and wave tail time, Multistage impulse generator, Modified Marx circuit, Tripping and control of impulse generators, Generation of high impulse current

Unit 05: **Measurement of High Voltage and High Currents:** **(6 hrs)**

Sphere gap voltmeter, electrostatic volt meter, generating voltmeter, peak reading voltmeter, resistive, capacitive and mixed potential divider , capacitance voltage transformer, cathode ray oscilloscope for impulse voltage and current measurement, measurement of dielectric constant and loss factor, partial discharge measurements. Measurement of high power frequency a.c using current transformer with electro-optical signal converter, Radio interference measurements.

Unit 06: **High Voltage Testing of Electrical Apparatus and H V Laboratories:** **(6 hrs)**

A) Testing of insulators and bushings, Power capacitors and cables testing, testing of surge arresters.
B) Design, planning and layout of High Voltage laboratory:-Classification and layouts, earthing and shielding of H.V. laboratories.

Learning Outcomes:

Students will able to

- Reproduce concepts in breadth with various concepts of breakdown phenomenon of solid, liquid and gaseous materials along with various causes of overvoltage and protection from them.
- List and reproduce various methods of generation and measurement of DC, AC and impulse high voltage.
- Demonstrate an ability to carry various DC. AC and impulse testing on high voltage equipments and materials.
- Apply safety measures, earthing, shielding for layout of HV apparatus required in High voltage laboratory.

List of Experiments:[Minimum eight experiments to be conducted from the given list]

1. To perform breakdown test on transformer oil and obtain constants of breakdown voltage equation and breakdown strength

2. Measurement of unknown high a.c. voltage using sphere gap
3. To obtain breakdown strength of composite insulation system.
4. Study of uniform and non uniform field in breakdown strength of air insulation system.
5. To study surface flashover on corrugated porcelain/polymeric insulation system.
6. To understand basic principle of corona and obtain audible and visible corona inception and extinction voltage under non uniform field.
7. To perform experiment on horn gap arrestor and understand arc quenching phenomenon.
8. To observe development of tracks and trees on polymeric insulation system.
9. Study of output voltage waveform of multistage voltage doublers circuit on CRO.
10. To evaluate power loss under corona at various voltage levels.
11. To perform experiment on rod gap arrestor.
12. To Study effect of barrier on breakdown voltage of air/ transformer oil.
13. Simulation of lightening and switching impulse voltage generator.
14. To perform various HV insulation tests on cables as per IS.

Industrial visit to high voltage equipment manufacturing industry/EHV substation.

Text Books:

1. C. L. Wadhwa, “High Voltage Engineering”, New Age International Publishers Ltd.
2. M. S. Naidu, V. Kamaraju, “High Voltage Engineering”, Tata McGraw Hill Publication Co. Ltd. New Delhi

Reference books:

1. E. Kuffel, W. S. Zaengl, J. Kuffel, “High Voltage Engineering Fundamentals”, Newnes Publication
2. Prof. D. V. Razevig Translated from Russian by Dr. M. P. Chourasia, “High Voltage Engineering”, Khanna Publishers, New Delhi
3. Ravindra Arora, Wolf Gang Mosch, “High Voltage Insulation Engineering”, New Age International Publishers Ltd. Wiley Estern Ltd.
4. High Voltage Engineering Theory and Practice by M. Khalifa Marcel Dekker Inc. New York and Basel.
5. Subir Ray, “An Introduction to High voltage Engineering” PHI Pvt. Ltd. New Delhi

Elective –III : 403149: HVDC and FACTS

Teaching Scheme			Examination Scheme	
Lectures	03	hrs/week	In-Sem Assessment	30
Practical	02	hrs/week	End-Sem Assessment	70
			Oral :	25
			TW:	25

Prerequisites:
Fundamental knowledge of Power Electronics and Power systems is required

Course Objectives:
- To provide students knowledge about modern trends in Power Transmission Technology
- To make students understand applications of power electronics in the control of power transmission
- To educate students for utilization of software such as PSCAD, MATLAB for power transmission and control

Unit 01: General back ground **(6 hrs)**

EHVAC versus HVDC transmission, power flow through HVDC link, Graetz circuit, equation for HVDC power flow bridge connection, control of DC voltage and power flow, effects of angle of delay and angle of advance commutation, CIA, CC and CEA control, twelve pulse converter operation Harmonics in HVDC systems.

Unit02: Multi terminal HVDC system **(6 hrs)**

HVDC system layout and placement of components, HVDC protection, grounding, multi terminal HVDC systems, configurations and types.

Unit 03:HVDC Light **(6 hrs)**

Introduction to VSC transmission, power transfer characteristics, structure of VSC link, VSC DC system control, HVDC light technology.

Unit 04: Power Electronic Controllers **(6 hrs)**

Basics, Challenges and needs, Review of rectifiers and inverters, back to back converter, dc link converter, static Power converter structures, AC controller based structures, DC link converter topologies, converter output and harmonic control, power converter control.

Unit05: Shunt and series compensation **(6 hrs)**

Operation and control of SVC, STATCOM configuration and control, applications of SVC and STATCOM. TCSC operation, layout and operation, static Synchronous series compensator (SSSC).

Unit 06: Unified Power Flow Controller (6 hrs)

UPFC configuration, steady state operation control and characteristics, operational constraints of UPFC, Power flow studies in UPFC embedded systems.

Learning Outcomes:

Student will be able to

- Analyze modeling of FACTs Controllers
- Simulate various controllers and HVDC systems using softwares such as PSCAD and MATLAB.
- Develop computer programs for power flow studies

Experiments:

Minimum eight experiments are to be performed out of the list mentioned as below:

1. Study of various FACTS Controllers models.
2. Study of Single Phase Thyristor Control Reactor(A) Study of Voltage and Current Waveforms with different delay angles (B) harmonic analysis (C) Basic control law (D) V-I characteristics
3. Single Phase TCR with fixed capacitor and filter.
4. Study and simulation of Three phase TCR with and without shunt capacitor
5. Study and simulation of resonance in electrical Power systems
6. Application study of SVC in Power System.
7. Application study of TCSC in Power System.
8. Application study of DSTATCOM in Power System
9. Application study of DVR in Power System
10. Study and simulation of Power Flow control in a five bus system using any one of the following FACTS Controllers:
    (i) SVC (ii) STATCOM (iii) SSSC (iii) UPFC
11. Study of Power factor corrector in Power System
12. Study and simulation of 6 pulse HVDC system
13. Study of 12 pulse or 24 pulse or 48 pulse inverter
14. Study of Series compensation of a three phase transmission line
15. Complete characteristics of a three phase voltage source converter[Hardware]Constant alpha and extinction angle control

Text Books:

1. E. Acha, V.A. Agelidis, O.Anaya-lara and TJE Miller, "Power Electronic control in Electrical Systems" Newnes, Oxford.
2. N.G. Hingorani and L.Gyugi, "Understanding FACTS" IEEE Press[Indian Edition], New York.
3. J. Arrilaga, Y.H.Liu and N.R.Watson, "Flexible Power Transmission The HVDC Options", John Wiley and sons Ltd., New York.

4. J. Arrillaga, “High Voltage Direct Current Transmission” Peter Peregrinus Ltd., London, UK.
5. Erich Uhlmann, “Power Transmission by Direct Current” Springer International.

Reference books:

1. Yong Hua Song & Allan T Johns, “Flexible ac transmission systems(FACTS), Published by The Institution of Electrical Engineers, London.
2. K.R.Padiyar, “FACTS controllers in transmission and Distribution” New Age Publications, New Delhi.
3. M.H.Rashid , “Power Electronics Handbook”, Academic Press.
4. K.R.Padiyar , “HVDC Power Transmission Systems”, New Age Publications, New Delhi, (2nd Edition)

Elective –III : 403149: Digital Control System

Teaching Scheme		**Examination Scheme**	
Lectures	**03 hrs/week**	**In-Sem Assessment**	**30**
Practical	**02 hrs/week**	**End-Sem Assessment**	**70**
		Oral	**25**
		TW	**25**

Prerequisite: Z-Transform, Basics of discrete systems.

Course Objectives:

- To make students understand basic concepts of discrete signals and systems.
- To educate students to analyze the stability of discrete systems.
- To teach formulation of state space discrete model and design the digital controllers.
- To elaborate digitize analog controllers using various numerical methods.
- To explore application of the theory of digital control to practical problems.

Unit 01: Discrete systems and Signals (6 hrs)

Standard discrete test signals, Basic operations on signals. Classification of discrete systems. Detail analysis of frequency aliasing & quantization, Brief review of Sampling theorem, Ideal low pass filter. Transfer function of ZOH, Frequency domain characteristics of ZOH, First order hold, frequency domain characteristics of first order hold.

Unit 02: Stability Analysis (6 hrs)

Brief review of pulse transfer function, mapping between S-plane and Z-plane, constant frequency loci and constant damping ratio loci. Stability analysis of closed loop system in the Z-Plane. Jury's stability test, Stability analysis by use of Bilinear transformation & Routh Stability Criterion. Digital compensator design using frequency response (Bode plot).

Unit 03: State - Space analysis (6 hrs)

Conversion of Pulse transfer functions to State space model and vice a versa. Solution of LTI Discrete –time state equation; State Transition Matrix (STM) and properties of STM; Computation of STM by Z-transform method, by power series expansion method, by Cayley Hamilton theorem, by Similarity transformation method, Discretization of continuous time state space equation.

Unit 04: Design using state space (5 hrs)

Controllability and observability of linear time invariant discrete-data system, Tests for Controllability and obervability; Principal of Duality; Effect of pole- zero cancellation; Relationship between controllability, observability and stability. Pole placement design using linear state-feedback. State estimation and full order observer design. Ackermann's formula.

Unit 05: State space model and digitising analog controllers (7 hrs)

State space model of digital systems: Transformation of state-space model to various forms (controllable, observable, diagonal and Jordan canonical forms).

Numerical approximation of differential equations, Eulers foreword & backward method, Trapezoidal method, Bilinear transformation with frequency warping. Numerical differentiation, Matching step & other response. Pole-zero matching.

Unit 06: Digital control system applications (6 hrs)

Hybrid system simulation, Computer program structure for simulation of discrete time control of continuous time plant.

Digital temperature control, position control, Stepper motor control, Block diagram presentation and control algorithms.

Learning Outcomes:

Students will be able to

- Differentiate between various control systems.
- Analyze digital control system and its stability.
- Elaborate applications such as digital temperature control and position control.
- Simulate digital control system by using computer software.

List of Experiments: Perform any eight experiments

Design & analysis of digital temperature control system

1. Design and analysis of digital position control system.
2. Software programming for determination of STM of DT system.
3. Software programming to design DT system by pole placement through state feedback.
4. Software programming for determination of controllability and observability of DT System.
5. Software programming to observe effect of sampling on response of the system
6. Software programming to observe effect of sampling on stability of DT system.
7. Solution of state equation of L.T.I. systems by the use of digital computer.
8. Digital computer aided difference equation solution.
9. Conversion of continuous time state space model to discrete time state space

Model.

Text Books:

1. K. Ogata, “Discrete Time Control System”, 2nd Edition, PHI Learning Pvt. Ltd. 2009
2. B. C. Kuo, “Digital Control Systems**”,** 2nd Edition, Oxford University Press
3. M. Gopal, “Digital Control Engineering”, New Age International Publishers
4. M. Gopal, “Digital Control and State Variable Methods”, 3rd Edition The McGraw Hill Co.

Reference books:

1. Load D. Landau, Gianluca Zito, ‘Digital Control Systems: design, Identification and Implementation’ Springer.
2. Mohammed Santina, Allen Stubberud, Gene Hostetter ‘Digital control System Design’, Sanders College publishing.
3. K.J. Astrom, B Wittenmark ‘Computer Controlled Systems: Theory and Design’ Prentice-Hall Inc New Jersey , 2011 Dover .

Elective – III : 403149: Intelligent Systems and its Applications in Electrical Engineering

Teaching Scheme		**Examination Scheme**	
Lectures	**03 hrs/week**	**In-Sem Assessment**	**30**
Practical	**02 hrs/week**	**End-Sem Assessment**	**70**
		Oral	**25**
		TW	**25**

Prerequisite:

Knowledge of MATLAB, C- Programming

Course Objectives:

- To enhance knowledge of intelligence system to carry out power system problems.
- To impart knowledge about Artificial neural network and fuzzy logic programming for electrical engineering applications like load dispatch and load shedding.

Unit 01: **Introduction to Artificial Neural Network:** **(6 hrs)**

Organization of the Brain, Biological Neuron, Biological and Artificial Neuron Models, Historical Developments. Essentials of Artificial Neural Networks: Artificial Neuron Model, operations of Artificial Neuron, Types of Neuron Activation Function, ANN Architectures

Unit 02: **Classification Taxonomy of ANN**: **(6 hrs)**

Connectivity, Neural Dynamics (Activation and Synaptic), Learning Strategy (Supervised, Unsupervised, Reinforcement), Learning Rules.

Perceptron Models: Training Algorithms: Discrete and Continuous Perceptron Networks, Perceptron Convergence theorem. Multilayer feed forward Neural Networks

Unit 03: **Memory:** **(6 hrs)**

Associative Memory, Bi-directional Associative Memory (BAM) Architecture, BAM Training Algorithms: Storage and Recall Algorithm, BAM Energy Function, Self-Organizing Maps (SOM) and Adaptive Resonance Theory (ART).

Unit 04: **Introduction to Fuzzy Logic system:** **(6 hrs)**

Fuzzy versus crisp, fuzzy sets: membership function, Basic fuzzy set operations, properties of fuzzy sets, fuzzy relations.

Unit 05: **Fuzzy Control:** **(6 hrs)**

Predicate logic (Interpretation of predicate logic formula, Inference in predicate logic), fuzzy logic (Fuzzy quantifiers, fuzzy Inference), fuzzy rule based system, defuzzification methods

Unit 06: **Introduction to other Intelligent tools:** **(6 hrs)**

Introduction to Genetic Algorithm: biological background, GA operators, selection, encoding, crossover, mutation, chromosome.

Expert System: software architecture, rule base system

Learning Outcomes:

Students will be able to

- Compare various AI tools
- Develop algorithms for AI tools
- Apply AI tools for Applications in electrical engineering.

List of Experiments:

Minimum eight experiments are to be performed out of the list mentioned as below:
[Matlab Programming based experiments.]

1. Write program to evaluate output of any given architecture of neural network with different transfer functions such as linear logsig tanh, threshold function.
2. Verify the fault tolerant nature of neural network by disconnecting few weight link for a given architecture
3. Write program for perceptron learning algorithm.
4. To study some basic neuron models and learning algorithms by using ANN tool
5. Power system failure analysis using ANN tool
6. Predict power factor of four bus system using neural network
7. Predict system analysis for measurements like rms voltage using ANN tool
8. Write supervised and unsupervised ANN program for Signal Frequency Separation using Perceptron
9. Temperature monitoring using fuzzy logic
10. Speed control of DC motor using fuzzy logic
11. Fuzzy logic based washing machine control
12. Fuzzy logic based air conditioner
13. Design of a Fuzzy Multi-Objective Power System Stabilizer via Linear Matrix Inequalities

Text Books:

1. Simon Haykin, “Neural Networks: A Comprehensive Foundation”, 2nd Edition, Pearson Education
2. S. Rajsekaram, G. A. Vijayalaxmi Pai, “Neural Networks, Fuzzy Logic & Genetic Algorithms Synthesis & Applications”, Practice Hall India
3. James A. Anderson, “An Introduction to Neural Networks”, Practice Hall India Publication
4. Mohamed H. Hassoun, “Fundamentals of Artificial Neural Network”, Practice Hall India

Reference books:

1. Kelvin Waruicke, Arthur Ekwlle, Raj Agarwal, “AI Techniques in Power System”, IEE London U.K.
2. S. N. Sivanandam, S. Sumathi, S. N. Deepa, “Introduction to Neural Network Using MATLAB 6.0”, Tata McGraw Hill
3. Jacek Zurada, “Introduction to Artificial Neural Network”, Jaico Publishing House India

Elective –IV : 403150 : Smart Grid

Teaching Scheme
Lectures: 03 hrs/week

Examination Scheme
In-Sem Assessment: 30
End-Sem Assessment: 70

Prerequisite: Knowledge of existing grid.

Course Objectives:

- To understand the concept of Smart Grid, compare with conventional grid, and identify its opportunities and barriers.
- To understand the concept of Smart Meter, Smart Appliances, Automatic Meter Reading, Outage Management System, Plug in Hybrid Electric Vehicles, Vehicle to Grid, Smart Sensors, Home & Building Automation, Phase Shifting Transformers.
- To understand the concept of Substation Automation, Feeder Automation. Intelligent Electronic Devices, Smart storage like Battery, Pumped Hydro, Compressed Air Energy Storage, Wide Area Measurement System, Phase Measurement Unit.
- To understand the concept of microgrid
- To understand the concept of Power Quality and its issues of Grid connected Renewable Energy Sources, Web based Power Quality monitoring, Power Quality Audit.

Unit 01: Introduction to Smart Grid: (6 hrs)

Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid, Drivers of SG in India, Challenges for SG, Difference between conventional & smart grid, Smart Grid Vision & Roadmap for India, Concept of Resilient and Self Healing Grid, Present development & International policies in Smart Grid, Smart Cities, Pilot projects in India.

Unit 02: Smart Grid Technologies: (6 hrs)

Remote Terminal Unit (RTU), Intelligent Electronic Devices (IED), Phase Measurement Unit (PMU).

Smart Substations, Substation and Feeder Automation, application for monitoring, protection and control, Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid(V2G), Grid to vehicles(G2V), Smart storage technologies – Battery(flow and advanced), SMES, Super Capacitors, Pumped Hydro, Compressed Air Energy Storage(CAES) and its comparison, Optimal Location of PMUs for Complete Observability.

Unit 03 Smart Meters and Advance Metering Infrastructure: (6 hrs)

Introduction to Smart Meters, Advanced Metering Infrastructure (AMI), Real Time Prizing, Automatic Meter Reading (AMR), Outage Management System (OMS) Smart Sensors, Smart Appliances, Home & Building Automation, Geographic Information System (GIS).

Unit 04 : Microgrids: (6 hrs)

Concept of Microgrid, need & applications of Microgrid, Microgrid Architecture, DC Microgrid, Formation of Microgrid, Issues of interconnection, protection & control of

Microgrid, Integration of renewable energy sources, Smart Microgrid, Microgrid and Smart Grid Comparison, Smart Microgrid Renewable Green Energy System, Cyber Controlled Smart Grid

Unit 05: Power Quality Management in Smart Grid: **(6 hrs)**

Power Quality and EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit

Unit 06: Communication Technology for Smart Grid: **(6 hrs)**

Communication Architecture of SG, Wide Area Measurement System (WAMS), Home Area Network (HAN), Neighbourhood Area Network (NAN), Wide Area Network (WAN). Bluetooth, ZigBee, GPS, Wi-Fi, Wi-Max based communication, Wireless Mesh Network, Basics of CLOUD Computing & Cyber Security for Smart Grid, Broadband over Power line (BPL), IP based protocols.

Learning Outcomes:

Student will be able to

- Differentiate Conventional and Smart Grid.
- Identify the need of Smart Grid, Micro Grid, Smart metering, Smart storage, Hybrid Vehicles, Home Automation, Smart Communication.
- Get introduced to new upcoming concepts in electrical from Utility to Consumers.
- Comparing and getting acquainted with emerging technologies and current professional issues in electric Grid.
- Express the necessity of global smart communication system

Text Books:

1. Ali Keyhani, Mohammad N. Marwali, Min Dai "Integration of Green and Renewable Energy in Electric Power Systems", Wiley
2. Clark W. Gellings, "The Smart Grid: Enabling Energy Efficiency and Demand Response",CRC Press
3. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, "Smart Grid: Technology and Applications", Wiley Publications.
4. Stuart Borlase, "Smart Grids-Infrastructure, Technology and Solutions", CRC Press, Taylor and Francis group
5. Janaka Ekanayake, Kithsiri Liyanage, Jianzhong Wu and Akihiko Yokoyama, "Smart Grid-Technology and applications", Wiley Publications.
6. James Momoh, "Smart Grid-Fundamentals of design and analysis", Wiley Publications.

Reference Books:

1. Nikos Ziargyriour, "Micro grid, Architecture and Control", IEEE Press, Wiley Publications.
2. Yang Xiao, "Communication and Networking in Smart Grids", CRC Press, Taylor and Francis group
3. Lars T. Berger and Krzysztof Iniewski, "Smart Grid-Applications, Communications and Security", Wiley Publications.
4. Mladen Kezunovic, Mark G. Adamiak, Alexander P. Apostolov, Jeffrey George Gilbert "Substation Automation (Power Electronics and Power Systems)", Springer Publications.

5. Stephen F.Bush, “Smart Grid-Communication Enabled Intelligence for the Electric Power Grid”, IEEE Press, Wiley Publications
6. R. C. Dugan, Mark F. McGranghan, Surya Santoso, H. Wayne Beaty, “Electrical Power System Quality”, 2nd Edition, McGraw Hill Publication.
7. Jean Claude Sabonnadière, Nouredine Hadjsaïd, “Smart Grids”, Wiley Blackwell

Elective – IV : 403150: Robotics and Automation

Teaching Scheme		**Examination Scheme**	
Lectures	**3 hrs/week**	**In-Sem Assessment**	**30**
		End-Sem Assessment	**70**

Course Objectives:

- To know basic parts of a typical industrial robot system with its anatomy with human body.
- To analyze mathematically kinematic and dynamic modeling of a typical robot manipulator.
- To select an appropriate type of robot with given specifications for different industrial applications.
- To know the basics of actuators, sensors and control of an industrial robot for different applications

Unit 01 : Introduction (6 hrs)

Robot components, Degrees of freedom, Robot joints, Robot reference frames,
Robot specifications: repeatability, spatial resolution, compliance, load carrying capacity, speed of response, work volume, work envelope, reach etc., end effectors (Wrist), concept of: yaw, pitch and roll. Robot classification: according to Co-ordinate system: Cartesian, cylindrical, spherical, SCARA, Articulated, Control Method: Servo controlled & non-servo controlled, their comparative study, Form of motion: P-T-P (point to point), C-P (continuous path), pick and place etc. and their comparative study

Unit 02: Mathematical preliminaries (6 hrs)

Homogeneous Coordinate, Translational Transformation, Rotational Transformation, coordinate reference frames, Effect of pre and post multiplication of transformation, Concept of Homogeneous transformation, Euler angles and singularities

Unit 03: Forward Kinematics: (6 hrs)

Denavit-Hartenberg (D-H) representation of kinematic chains. Rules for establishing link co-ordinate frames. Forward solution of robotic manipulator for SCARA Robot and PUMA Robot. Forward solution for simple robot systems.

Unit 04: (6 hrs)

Inverse Kinematics: Concept of Inverse Kinematics, general properties of inverse solution such as existence and uniqueness of solution, inverse solution by direct approach, Geometric approach, inverse solution for simple SCARA Robots, numericals for simple three axis robots based on direct approach.

Robot Dynamics: Lagrange's Equation, Kinetic and potential energy Equations, Euler-Lagrange analysis for a single prismatic joint working against gravity and single revolute joint. Equation of motion.

Unit 05: Differential motion and Control **(6 hrs)**

Manipulator Differential Motion: Concept of linear and angular velocity, Relationship between transformation matrix and angular velocity, manipulator Jacobian, Jacobian for prismatic and revolute joint, Jacobian Inverse, Singularities.

Control of Robot Arm: Modeling of DC motor and load, closed loop control in position servo, the effect of friction and gravity, control of a robotic joint, position velocity and acceleration profiles for trapezoidal velocity profile.

Control of Robot manipulator: joint position controls (JPC), resolved motion position controls (RMPC) & resolved motion rate control (RMRC).

Unit 06: Actuators and sensors: **(6 hrs)**

Drive Technology: Hydraulic, Pneumatic, Electric (stepper motor, D.C. servo motor, BLDC Motors) in detail with selection criteria. Sensors in servocontrol system: Resolver, rotary shaft encoders, potentiometers, tacho-generators.

Industrial Applications of Robots: Welding, Spray-painting, Grinding, Handling of rotary tools, Parts handling/transfer, Assembly operations, parts sorting, parts inspection, Potential applications in Nuclear and fossil fuel power plant etc. (Details for the above applications are selection criterion of robots, sensors used, selection of drives and actuators, methods of control, peripheral devices used etc).

Learning Outcomes:

At the end of the course, a student will be able to –

- Differentiate between types of robots based on configuration, method of control, types of drives, sensors used etc.
- Choose a specific robot for specific application with given specifications.
- Analyze the robot arm dynamics for calculation of torques and forces required for different joints of robots for control of robot arm.
- Determine the D-H parameters for a robot configuration using concepts from robot arm kinematics which further leads to forward/inverse kinematics.
- Calculate the Jacobian matrix for robot arm velocity and decide the singular positions.

Industrial Visit:

At least one industrial visit should be arranged supporting the classroom teaching and student should submit a report on that industrial robot application including type of robot, method of control, type of application, sensor interface, method of programming etc.

Text Books:

1. Mikell P. Groover, Mitchell Weiss, Roger N. Nagel, Nicholas G. Odrey, Ashish Dutta, “Industrial Robotics:

Technology, Programming and Applications", Tata- McGraw Hill Education Private Limited, New Delhi, 2012.
2. Richard D. Klafter, Thomas A. Chemielewski, Michael Neign, "Robotic Engineering – An Integral Approach", Prentice Hall of India Pvt. Ltd., New Delhi. Eastern Economy Edition
3. Robert J. Schilling, "Fundamentals of Robotics: Analysis and Control", Prentice Hall of India, New Delhi

Reference Books:

1. K. S. Fu, R. C. Gonzalez, C. S. G. Lee, "Robotics: Control Sensing, Vision and Intelligence", International Edition, McGraw Hill Book Co.
2. John J. Craig, "Introduction to Robotics: Mechanics and Control", Pearson Education
3. R. K. Mittal, I. J. Nagrath, "Robotics and Control", Tata McGraw Hill Publishing Company Ltd., New Delhi
4. Saeed b. Niku, "Introduction to Robotics: Analysis, Control, Applications", Wiley Publication, 2011.

Elective IV :403150: Illumination Engineering

Teaching Scheme

Lectures **03 hrs/week**

Examination Scheme

In-Sem Assessment **30**

End-Sem Assessment **70**

Prerequisites-

1) The working of the conventional lamps must be known.
2) The generation of light and physics of light must be known.
3) The techniques for natural and artificial lighting must be known.

Course Objectives-

- To get the detailed information about modern lamps and their accessories.
- To get detailed insight of indoor and outdoor illumination system components, its controls and design aspects.
- To know the requirements of energy efficient lighting.
- To introduce the modern trends in the lighting

Unit 01: Importance of Lighting in Human Life: **(6 hrs)**

Optical systems of human eye ,Dependence of human activities on light, performance characteristics of human visual system, External factors of vision-visual acuity, contrast, sensitivity, time illuminance, colour, visual perception, optical radiation hazards, Good and bad effects of lighting & perfect level of illumination, Artificial lighting as substitute to natural light, Ability to control natural light, Production of light, physics of generation of light, Properties of light, Quantification & Measurement of Light.

Unit 02: Light Sources: **(6 hrs)**

Lamp materials: Filament, glass, ceramics, gases, phosphors and other metals and non-metals.
Discharge Lamps: Theory of gas Discharge phenomena, lamp design considerations, characteristics of low and high mercury and Sodium vapour lamps, Low Vapour Pressure discharge lamps - Mercury Vapour lamp, Fluorescent Lamp, Compact Fluorescent Lamp (CFL)
High Vapour Pressure discharge lamps - Mercury Vapour lamp, Sodium Vapour lamp, Metal halide Lamps, Solid Sodium Argon Neon lamps, SOX lamps, Electro luminescent lamps, Induction lamps.

Unit 03 : Electrical Control of Light Sources: **(6 hrs)**

Ballast, ignitors and dimmers for different types of lamps,
Photometric Control of Light Sources and their Quantification:
Types of Luminaries, factors to be considered for designing luminaries
Types of lighting fixtures.
Optical control schemes, design procedure of reflecting and refracting type of luminaries. Lighting Fixture types, use of reflectors and refractors, physical protection of lighting fixtures, types of lighting

fixtures according to installation type, types of lighting fixtures according to photometric usages, luminaries standard (IEC-598-Part I).

Unit 04: **(6 hrs)**

Zonal cavity method for general lighting design, determination for zonal cavities and different shaped ceilings using COU (coefficient of utilization), beam angles and polar diagrams. Factors to be considered for design of indoor illumination scheme

Indoor illumination design for following installations

- Residential (Numerical)
- Educational institute
- Commercial installation
- Hospitals
- Industrial lighting

Special purpose lighting schemes

- Decorative lighting
- Theatre lighting
- Aquarium, swimming pool lighting

Unit 5: **(6 hrs)**

Factors to be considered for design of outdoor illumination scheme

Outdoor Lighting Design: Road classifications according to BIS, pole arrangement, terminology, lamp and luminaire selection, different design procedures, beam lumen method, point by point method, isolux diagram, problems on point by point method.

Outdoor illumination design for following installations

- Road lighting (Numerical)
- Flood lighting (Numerical)
- Stadium and sports complex
- Lighting for advertisement/hoardings

Unit 06 : Modern trends in illumination **(6 hrs)**

- LED luminary designs
- Intelligent LED fixtures
- Natural light conduiting
- Organic lighting system
- LASERS, characteristics, features and applications, non-lighting lamps
- Optical fiber, its construction as a light guide, features and applications

Course Outcomes:

Student will be able to

1. Define and reproduce various terms in illumination.
2. Identify various parameters for illumination system design.
3. Design indoor and outdoor lighting systems.
4. Enlist state of the art illumination systems.

Text Books:

1. H. S. Mamak, “Book on Lighting”, Publisher International lighting Academy
2. Joseph B. Murdoch, “Illumination Engineering from Edison’s Lamp to Lasers” Publisher -York, PA : Visions Communications
3. M. A. Cayless, A. M. Marsden, “Lamps and Lighting”, Publisher-Butterworth-Heinemann(ISBN 978-0-415-50308-2)
4. Designing with light: Lighting Handbook., Anil Valia; Lighting System 2002

Reference Books:

1. “BIS, IEC Standards for Lamps, Lighting Fixtures and Lighting”, Manak Bhavan, New Delhi
2. D. C. Pritchard, “Lighting”, 4th Edition, Longman Scientific and Technical, ISBN 0-582-23422-0.
3. “IES Lighting Handbook”, (Reference Volume 1984), Illuminating Engineering Society of North America.
4. “IES Lighting Handbook”, (Application Volume 1987), Illuminating Engineering Society of North America
5. IESNA lighting Handbook., Illuminating Engineering Society of North America 9th edition 2000
6. Applied Illumination Engineering, Jack L. Lindsey FIES (Author), Scott C. Dunning PHD PE CEM (Author) ,ISBN-13: 978-0824748098 ISBN-10: 0824748093, 3rd Edition.
7. IS 3646: Part I: 1992, *Code of practice for interior illumination.*
8. Organic Light Emitting Diodes (OLEDs): Materials, Devices and Applications, Alastair Buckley, University of Sheffieid, UK, ISBN: 978-0-85709-425-4.

Elective IV :403150 : VLSI Design

Teaching Scheme

Lectures 03 hrs/week

Examination Scheme

In-Sem Assessment 30

End-Sem Assessment 70

Course Objectives:

- To understand Modeling of Digital Systems Domains for different combinational and sequential circuits
- To understand Levels of Modeling using Modeling Language VHDL.
- To Understand Modeling and programming Concepts by Learning a New Language
- To develop of logic design and programming skills in HDL language.
- To study HDL based design approach.
- To learn digital CMOS logic design

Unit 01 : Overview of Digital Logic Circuits and Introduction to VLSI: (6 hrs)

Combinational circuits: Decoders, Multiplexer, ALU. Sequential circuits: latch, flip flop – RS, JK, D,T., shift registers ,Counters, Moore, Mealy Machines

Introduction to VLSI: complete VLSI design flow (with reference to an EDA tool), IEEE Standards ,VHDL Terms Definitions – Entity, architecture, Schematic, Components, Configuration.

Unit 02 : VHDL Modeling (6 hrs)

Data objects, Data types, Entity, Architecture & types of modeling: Behavioral, data flow, & Structural with the help of digital functions like multiplexer, Shift Register, counter. Sequential statements, Concurrent statements. VHDL Test bench. VHDL modeling of Combinational, Sequential logics.

Unit 03 : VHDL and Finite State Machines (6 hrs)

Synthesizable and non synthesizable statements, functions, procedures, attributes, configurations, packages. Synchronous and asynchronous machines, Finite State Machines (FSM), metastability, state diagrams and VHDL codes for FSMs.

Unit 04 : Programmable Logic Devices (PLDs) (6 hrs)

Need of PLDs. Comparison with ASIC, general purpose processor, DSP processor, microcontroller, memories etc. Features, specifications, detail architectures, application areas, limitations of Complex Programmable Logic Device (CPLD) and Field Programmable Logic Devices (FPGA).

Unit 05 : Digital CMOS Design (6 hrs)

CMOS INVERTER, CMOS NAND and CMOS NOR, voltage transfer curve, body effect, hot electron effect, velocity saturation. Static and dynamic dissipations. Power delay product. Noise margin. Combinational logic design, , comparison of CMOS and NMOS. Comparative study of TTL, ECL, CMOS .

Unit 06 : **(6 hrs)**

VLSI Design Applications: Barrel shifter, signed and unsigned comparators, Carry ripple and carry look, Ahead address, Fixed- point division, serial data receiver, parallel to serial converter, playing with a seven segment display and key board, signal generators, memory design, Vending - Machine controller.

Learning Outcomes:

Student will be able to

- Design and develop combinational and sequential digital logic circuits using different techniques.
- Analyze and design basic central processing units and memory systems for general-purpose computers.
- Use appropriate techniques and modern digital-systems development tools for Digital circuits.
- Model digital circuit with HDL and simulate

Text Books:

1. Douglas Perry, “VHDL”, Tata McGraw Hill.
2. John F. Wakerly, “Digital Design, Principles and Practices”, Prentice Hall Publication
3. Wolf, “Modern VLSI Design”, Pearson Education.
4. R.P.Jain, “Modern Digital electronics”, 3rd edition, Tata McGraw-Hill.
5. Donald P. Leach, Albert Paul Malvino, “Digital Principles and Applications”, Glencoe Publisher.
6. Neil H. Weste and Kamran, “Principles of CMOS VLSI Design”, Pearson Publication.

Reference Books:

1. Charles H. Roth, “Digital System Design Using VHDL”, PWS Publishing Company (Thomson Learning)
2. Sung-Mo(Steve) Kang, Yusuf Leblebici, “CMOS Digital Integrated Circuits”, Tata McGraw Hill Publication.
3. J. Bhaskar, “VHDL Primer”, 3rd Edition, Addison Wesley Longman Singapore Pte Ltd.
4. Volner A. Dedroni, “Circuit Design with VHDL”, PHI Publications
5. Xilinx Data Manual “The Programmable Logic Data Book”.
6. Lizy Kurian John, “Principles of Digital Systems Design and VHDL” Paperback – 2008 .
7. Peter J. Ashenden (Author), Jim Lewis, “ VHDL-2008: Just the New Stuff”, (Systems on Silicon) Paperback – Import, 7 Dec 2007.
8. Data Sheets of PLDs.

403146: Project

Teaching Scheme		Examination Scheme	
Tutorial	**6 Hrs/Week**	**OR**	**100**
		TW	**50**

Course Objectives:

1. To develop skills for carrying literature survey and organize the material in proper manner.
2. To provide opportunity of designing and building complete system/subsystem based on their knowledge acquired during graduation.
3. To understand the needs of society and based on it to contribute towards its betterment and to learn to work in a team.
4. To explore and to acquire specified skill in areas related to Electrical Engineering
5. To ensure the completion of given project such as fabrication, conducting experimentation, analysis, validation with optimized cost.
6. Collect the data in report form and represent and communicate findings of the completed work in written and verbal form.

Guidelines for VIIIth Semester for Project Work

The student shall complete the remaining part of the project which is an extension of the work carried out in 7th Semester. Remaining part of the project consists of design, simulation, fabrication of set up required for the project, analysis and validation of results and conclusions.

The student shall prepare duly certified final report of the project work in the standard format.

Course outcomes:

Students will be able to
1. Work in team and ensure satisfactory completion of project in all respect.
2. Handle different tools to complete the given task and to acquire specified knowledge in area of interest.
3. Provide solution to the current issues faced by the society.
4. Practice moral and ethical value while completing the given task.
5. Communicate effectively findings in verbal and written forms.