Rajiv Gandhi University of Knowledge Technologies

Electrical and Electronics Engineering

R18 & R19_CREDIT DISTRIBUTION FOR PROGRAMME ELECTIVES

S. No	Course Code	Course Title	Semester	Course Category	Hours per week			Total Contact Hours	Credits
					L	T	P		
1.	EEPE11 EEPE12 EEPE13	Power Semiconductor Drives Special Machines Reliability Engineering	VI	PEC	3	0	0	3	3
2.	EEPE21 EEPE22 EEPE23	Digital Control Systems Wind and Solar Energy Systems Line Commutated and Active Rectifiers	VI	PEC	3	0	0	3	3
3.	EEPE31 EEPE32 EEPE33	HVDC Transmission Control Systems Design Digital Signal Processing	VII	PEC	3	0	0	3	3
4.	EEPE41 EEPE42 EEPE43	Switched Mode Power Supplies Smart Grid Artificial Neural Networks and Fuzzy Systems	VII	PEC	3	0	0	3	3
5.	EEPE51 EEPE52 EEPE53	Power Quality and FACTS Electrical and Hybrid Vehicles High Voltage Engineering	VIII	PEC	3	0	0	3	3

Department may offer any other emerging topic (apart from above mentioned) in the field of electrical engineering based on demand and availability of experts in the particular topic.

EEPE11 **SPECIAL MACHINES**

Externals: 60Marks **L-T-P-C**

Internals: 40Marks **3-0-0-3**

Course Objective:

- To understand the working principle and construction of stepper motors and switched reluctance motors.
- Demonstrate the ability to understand the construction of ,Amplidyne ,Metadyne and Regulex- third brush generator
- To gain knowledge in principle of operation and characteristics of permanent magnet

Course Outcome: At the end of the course the student will be able to:

- Identify the different features of special machines.
- Perform and analyze different methods to find Torque Pulsations for 180 degrees pole arc and 120 degree current sheet Brushless dc motors
- Elucidate the working and characteristics of stepper motors, VRSM motor and PMMM motor.

UNIT I : Special Types Of D.C Machines (8 Hours)

Series booster-Shunt booster-Non-reversible boost-Reversible booster
Armature excited machines—Rosenberg generator- The Amplidyne and metadyne— Rototrol and Regulex-third brush generator-three-wire generator-dynamometer.

UNIT II: Stepper Motors (9 Hours)

Introduction-synchronous inductor (or hybrid stepper motor), Hybrid stepping motor, construction, principles of operation, energisation with two phase at a time- essential conditions for the satisfactory operation of a 2-phase hybrid step motor- very slow- speed synchronous motor for servo control-different configurations for switching the phase windings-control circuits for stepping motors-an open-loop controller for a 2-phase stepping motor.

UNIT III: VR Stepping Motors and Switched Reluctance Motor(10 Hours)

Variable reluctance (VR) Stepper motors, single-stack VR step motors, Multiple stack VR motors-Open-loop control of 3-phase VR step motor-closed-Loop control of step motor, discriminator (or rotor position sensor) transilator, major loop-characteristics of step motor in open-loop drive – comparison between open-loop position control with step motor and a position control servo using a conventional (dc or ac) servo motor- Suitability and areas of application of stepper motors-5- phase hybrid stepping motor-single phase-stepper motor, the construction, operating principle torque developed in the motor.

Switched Reluctance Motor:

Introduction – improvements in the design of conventional reluctance motors- Some distinctive differences between SR and conventional reluctance motors-principle of operation of SRM- Some design aspects of stator and rotor pole arcs, design of stator and rotor and pole arcs in SR motor- determination of L(θ)--- θ profile –power converter for SR motor-A numerical example – Rotor sensing mechanism and logic control, drive and power circuits, position sensing of rotor with Hall problems—derivation of torque expression, general linear case.

UNIT IV: Permanent Magnet Motors and Brushless Dc Motor(10 Hours)

Permanent Magnet Motors: Introduction, Hysteresis loops and recoil line- stator frames (pole and yoke - part) of conventional PM dc Motors, Equivalent circuit of a PM-Development of Electronically commutated dc motor from conventional dc motor.

Brushless Dc Motor: Types of construction – principle of operation of BLDM- sensing and switching logic scheme, sensing logic controller, lockout pulses –drive and power circuits, Base drive circuits, power converter circuit-Theoretical analysis and performance prediction, modeling and magnet circuit d-q analysis of BLDM -transient analysis formulation in terms of flux linkages as state variables-Approximate solution for current and torque under steady state – Theory of BLDM as variable speed synchronous motor (assuming sinusoidal flux distribution)- Methods or reducing Torque Pulsations, 180 degrees pole arc and 120 degree current sheet.

UNIT V: Linear Induction Motor (5 Hours)

Development of a double sided LIM from rotary type IM- A schematic of LIM drive for electric traction development of one sided LIM with back iron-field analysis of a DSLIM fundamental assumptions.

TEXT BOOKS

1. K.Venkataratnam, Special electrical machines, university press.
2. R.K. Rajput - Electrical machines - 5th edition.
3. V.V. Athani - Stepper motor: Fundamentals, Applications and Design, New age

International publishers.

EEPE12 **WIND AND SOLAR ENERGY SYSTEMS**

Externals: 60Marks **L-T-P-C**

Internals: 40Marks **3-0-0-3**

Course Objectives:

- To understand the basic aspects of renewable energy supply presenting fundamental characteristics of resource base (solar radiation, wind energy..etc).
- To understand the issues related to energy supply systems.

Course Outcomes: At the end of the course the student will be able to:

- Understand the energy scenario and the consequent growth of the power generation from renewable energy sources.
- Understand the basic physics of wind and solar power generation. Understand the power electronic interfaces for wind and solar generation.
- Understand the issues related to the grid-integration of solar and wind energy system

UNIT I: Physics of Wind Power: (5 Hours)

History of wind power, Indian and Global statistics, Wind physics, Betz limit, Tip speed ratio, stall and pitch control, Wind speed statistics-probability distributions, Wind speed and power-cumulative distribution functions.

UNIT II: Wind generator topologies: (12 Hours)

Review of modern wind turbine technologies, Fixed and Variable speed wind turbines, Induction Generators, Doubly-Fed Induction Generators and their characteristics, Permanent- Magnet Synchronous Generators, Power electronics converters. Generator-Converter configurations, Converter Control.

UNIT III: The Solar Resource: (11 Hours)

Introduction, solar radiation spectra, solar geometry, Earth Sun angles, observer Sun angles, solar day length, Estimation of solar energy availability.

Solar photovoltaic:

Technologies-Amorphous, monocrystalline, polycrystalline; V-I characteristics of a PV cell, PV Unit, array, Power Electronic Converters for Solar Systems, Maximum Power Point Tracking (MPPT) algorithms. Converter Control.

UNIT IV: Network Integration Issues: (8 Hours)

Overview of grid code technical requirements. Fault ride-through for wind farms - real and reactive power regulation, voltage and frequency operating limits, solar PV and wind farm behavior during grid disturbances. Power quality issues. Power system interconnection experiences in the world. Hybrid and isolated operations of solar PV and wind systems.

UNIT V: Solar thermal power generation: (4 Hours)

Technologies, Parabolic trough, central receivers, parabolic dish, Fresnel, solar pond, elementary analysis

Text / References:

1. T. Ackermann, " Wind Power in Power Systems" , John Wiley and Sons Ltd., 2005.

2. G. M. Masters, "Renewable and Efficient Electric Power Systems", John Wiley and Sons, 2004.
3. S. P. Sukhatme, " Solar Energy: Principles of Thermal Collection and Storage", McGraw Hill, 1984.
4. H. Siegfried and R. Waddington, " Grid integration of wind energy conversion systems" John Wiley and Sons Ltd., 2006.
5. G. N. Tiwari and M. K. Ghosal, " Renewable Energy Applications", Narosa Publications, 2004.
6. J. A. Duffie and W. A. Beckman, " Solar Engineering of Thermal Processes" , John Wiley & Sons, 1991.

EEPE13 **POWER SEMICONDUCTOR DRIVES**

Externals: 60Marks **L-T-P-C**

Internals: 40Marks **3-0-0-3**

Course Objectives: This course will develop students' knowledge in/on

- The fundamentals and dynamics of electric drives
- The various types of the rectifier control and chopper control DC drives
- The AC voltage control, frequency control and slip power recovery control of Induction motor drives.
- Various types of synchronous motor drives and its speed torque characteristics

Course Outcomes: At the end of the course the student will be able to:

- Understand the fundamentals and dynamics of electric drives
- Develop the rectifier control and chopper control DC drives
- Realize the Concept of AC voltage control, frequency control and slip power recovery control of induction motor drives & Solve Problems
- Know the concept of Synchronous motor drives & Solve Problems

UNIT I: Fundamentals of Electric Drives(6 hours)

Electric Drives, advantages of electric drives, parts of electric drives, choice of electric drives, status of D.C. drives and A.C. drives. starting, Braking, speed control of AC and DC motors

UNIT II: Dynamics of Electric drives (8 hours)

Fundamental torque equations, types of load, Quadrant diagram of speed-Torque characteristics, Dynamics of load torque combinality, steady state stability and Transient stability of an Electric drives. Load equalization. Calculation of time and energy loss in Transient operation, Drive specifications.

UNIT III: Control of dc drives (10 hours)

Controlled rectifier circuits, braking operation of rectifier controlled separately excited dc motor, single phase and three phase half and fully controlled rectifier fed separately excited dc motor ,multi quadrant operation of fully controlled rectifier fed separately excited dc motor. Chopper control of dc drives : chopper control of separately excited and series dc motors , multi quadrant control of chopper fed motors

UNIT IV: Control of Induction Motor Drives AC Voltage Controllers: (10 hours)

Control of induction motor by AC voltage controllers. Frequency controlled Induction motor drives: control of Induction motor by Voltage Source Inverter (VSI),), Current controlled PWM inverters and cyclo converters.Slip power controlled wound-rotor induction motor drives: static rotor resistance control, static scherbius drives, krammer drives

UNIT V: Control of Synchronous Motor Drives (8 Hours)

Operation of cylindrical rotor synchronous motor from VSI and CSI, self controlled Synchronous Motor Drives using cyclo converters, Permanent magnet AC motor drives

Text Books:

1. G.K. Dubey, “Fundamentals of Electrical Drives”, Narosa Publishers, New Delhi. 1988
2. N.K. De and P.K. Sen, “Electrical Drives”, Prentice Hall of India, New Delhi. 1999

Reference Books:

1. Vedam Subrahmanyam, “Thyristor Control of Electrical Drives”, Tata McGraw Hill, New Delhi. 1988.
2. B.K. Bose “Modern Power Electronics & A.C Drives’.Pearson .edu
3. P.S.Bimbhra “ Power Electronics” Khanna publishers
4. G.K. Dubey, “Power Semiconductor Drives”, Narosa Publishers, New Delhi. 1988

EEPE21 **DIGITAL CONTROL SYSTEMS**

Externals: 60Marks **L-T-P-C**

Internals: 40Marks **3-0-0-3**

Course Objectives:

- This course introduces the concepts of Digital control systems and different types of
- Z-Transforms
- It discusses the design of different controllers, state equations of discrete data systems and stability analysis of discrete systems
- Analyze discrete control systems using z-transforms and stability of discrete control systems
- Design discrete control systems via pole placement
- Design observers for discrete control systems

UNIT I: Introduction To Digital Control Systems And Z-Transforms (9 Hours)

Introduction - Merits and Demerits of Digital Control Systems - Practical aspects of the choice of sampling rate and Multirate sampling - Basic discrete time signals - Quantization – Sampling Theorem - Data Conversions and Quantization - Sampling process - Mathematical Modeling - Data Reconstruction and Filtering of sampled signals - Zero - Order Hold (ZOH). z- Transform and Inverse z-Transform, Relationship between s - plane and z - plane - Difference equation - Solution by recursion and z-Transform - Pulse Transfer Functions of the ZOH and relationship between G(s) and G(z) - Bilinear Transformation .

UNIT II: Input/output Analysis Of Digital Control Systems (8 Hours)

Pulse transfer function - z transform analysis of open loop, closed loop systems - Modified z Transform - transfer function - Stability of linear digital control systems - Stability tests – Jury Stability test. Root loci - Frequency domain analysis - Bode plots - Gain margin and phase margin.

UNIT III: Design Of Controllers For I/O Model Digital Control Systems (9 Hours)

Cascade and Feedback Compensation by continuous data controllers - Digital controllers - Design using Bilinear Transformation - Realization of Digital PID controllers, Design of Digital Control Systems based on Root Locus Technique.

UNIT IV: State Space Analysis And State Feedback Control Design Of Digital Control Systems (9 Hours)

State Equations of discrete data systems, solution of discrete state equations, State Transition Matrix: Computation methods for State Transition Matrix: z - transform method - Relation between State Equations and Pulse Transfer Functions. Concepts on Controllability and Observability - Pole placement design by state feedback.

UNIT V: Digital State Observer And Stability Analysis (6 Hours)

Design of the full order and reduced order state observer, Design of Dead beat Controller - some case studies - Stability analysis of discrete time systems based on Lyapunov approach.

Text Books:

1 K. Ogata, Discrete Time Control Systems, PHI/Addison - Wesley Longman Pte. Ltd., India, Delhi,1995.
2 B.C Kuo, Digital Control Systems, 2nd Edition, Oxford University Press, Inc., 1992.

Reference Books:

1. F. Franklin, J.D. Powell, and M.L. Workman, Digital control of Dynamic Systems,
2. Addison - Wesley Longman, Inc., Menlo Park, CA , 1998.
3. M. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill, India, 1997.
4. C. H. Houpis and G.B. Lamont, Digital Control Systems, McGraw Hill, 1985.
5. John S. Baey, Fundamentals of Linear State Space Systems, McGraw Hill, 1st edition.
7. Dorsay, Continuous and Discrete Control Systems, McGraw Hill.

EEPE22 **RELIABILITY ENGINEERING**

Externals: 60Marks **L-T-P-C**

Internals: 40Marks **3-0-0-3**

Course Objectives:

- The course covers principles of reliability, failure rate and its relation to reliability, probability distribution of the time to failure, exponential and weibull distributions, reliability of systems, series and parallel systems, stand by redundancy, systems mean time to failure, mean residual life, reliability in design.
- It also includes failure mode effect analysis, failure tree analysis, reliability testing and analysis, And warranty problems

Course Outcomes: At the end of the course the student will be able to:

- Have a working knowledge of the techniques of reliability engineering
- To apply learned concepts to improving the maintenance, the maintainability, hazard risk and the safety of a plant.
- Develop warranty plans for different products
- To carry out a failure mode effect and criticality analysis.

UNIT I: Basic Probability Theory(9 Hours)

Elements of probability, probability distributions, Random variables, Density and Distribution functions- Binomial distribution- Expected value and standard deviation - Binomial distribution, Poisson distribution, normal distribution, exponential distribution, Weibull distribution.

Definition of Reliability

Definition of terms used in reliability, Component reliability, Hazard rate, derivation of the reliability function in terms of the hazard rate. Hazard models - Bath tub curve, Effect of preventive maintenance. Measures of reliability: Mean Time to Failure and Mean Time Between Failures.

UNIT II: Network Modeling And Evaluation Of Simple Systems(8 Hours)

Basic concepts- Evaluation of network Reliability / Unreliability - Series systems, Parallel systems - Series-Parallel systems- Partially redundant systems- Examples.

Network Modeling and Evaluation of Complex systems

Conditional probability method- tie set, Cutset approach- Event tree and reduced event tree methods-Relationships between tie and cutsets- Examples.

UNIT III: Time Dependent Probability(8 Hours)

Basic concepts- Reliability function f(t). F(t), R(t) and h(t) - Relationship between these functions.

Network Reliability Evaluation Using Probability Distributions

Reliability Evaluation of Series systems, Parallel systems – Partially redundant systems-determination of reliability measure- MTTF for series and parallel systems – Examples.

UNIT IV: Discrete Markov Chains(6 Hours)

Basic concepts- Stochastic transitional probability matrix- time dependent probability evaluation-Limiting State Probability evaluation- Absorbing states –Examples

Continuous Markov Processes

Modeling concepts- State space diagrams- Unreliability evaluation of single and two component repairable systems

UNIT V: (8 Hours)

Frequency And Duration Techniques: Frequency and duration concepts, application to multi state problems, Frequency balance approach.

Approximate System Reliability Evaluation: Series systems – Parallel systems- Network reduction techniques- Cut set approach- Common mode failures modeling and evaluation techniques- Examples.

TEXT BOOKS

1. Roy Billinton and Ronald N Allan, Reliability Evaluation of Engineering Systems, Plenum Press.
2. E.Balagurusamy, Reliability Engineering by Tata McGraw-Hill Publishing Company Limited

EEPE31 **HIGH VOLTAGE ENGINEERING**

Externals: 60Marks **L-T-P-C**

Internals: 40Marks **3-0-0-3**

Course Objectives:

- To develop knowledge on generation of high voltage DC, AC (power frequency and high frequency), impulse voltages and currents
- To know the measurement of high voltages DC, AC (power frequency and high frequency), impulse voltages and currents
- To understand thoroughly various high voltage testing techniques of power apparatus and Insulation coordination in power systems

Course Outcomes: At the end of the course the student will be able to:

- Understand breakdown phenomena in gases and to elucidate the concepts used for the generation of high voltages and currents.
- Elucidate the concepts used for the measurement of high voltages and currents and design Corresponding circuits.
- Understand high voltage testing techniques of Power apparatus and causes of over voltage in Power systems.
- Design the layout of Gas Insulated substations and to know the concepts of insulation coordination.

UNIT I: Introduction To High Voltage Technology And Applications (7 Hours)

Electric Field Stresses, Gas / Vacuum as Insulator, Liquid Dielectrics, Solids and Composites, Estimation and Control of Electric Stress, Numerical methods for electric field computation, Surge voltages, their distribution and control, Applications of insulating materials in transformers, rotating machines, circuit breakers, cable power capacitors and bushings.

UNIT II: Break Down in Solid Dielectrics Gaseous and Liquid Dielectrics(8 Hours)

Gases as insulating media, collision process, Ionization process, Townsend's criteria of breakdown in gases, Paschen's law - Liquid as insulator, pure and commercial liquids - breakdown in pure and commercial liquids.

Break Down In Solid Dielectrics

Intrinsic breakdown, electromechanical breakdown, thermal breakdown, breakdown of solid dielectrics in practice, Breakdown in composite dielectrics, solid dielectrics used in practice.

UNIT III: Generation of Measurement High Voltages And Currents(9 Hours)

Generation of High Direct Current Voltages, Generation of High alternating voltages, Generation of Impulse Voltages, Generation of Impulse currents, Tripping and control of impulse generators.

Measurement Of High Voltages And Currents

Measurement of High Direct Current voltages, Measurement of High Voltages alternating and impulse, Measurement of High Currents-direct, alternating and Impulse, Oscilloscope for impulse voltage and current measurements.

UNIT IV :Non-Distructive Testing Of Material And Electrical Apparatus(7Hours)

Measurement of D.C Resistivity, Measurement of Dielectric Constant and loss factor, Partial discharge measurements.

High Voltage Testing Of Electrical Apparatus: Testing of Insulators and bushings, Testing of Isolators and circuit breakers, testing of cables, Testing of Transformers, Testing of Surge Arresters, and Radio Interference measurements**.**

UNIT V: Over Voltage Phenomenon And Insulation Co-Ordination (7 Hours)

Natural causes for over voltages – Lightning phenomenon, Overvoltage due to switching surges, system faults and other abnormal conditions, Principles of Insulation Coordination on High voltage and Extra High Voltage power systems.

Text books:

1. M.S.Naidu and V. Kamaraju , High Voltage Engineering by– TMH Publications, 3rd Edition
2 . E.Kuffel, W.S.Zaengl, J.Kuffel , High Voltage Engineering: Fundamentals by Elsevier, 2nd Edition.

Reference books:

3. C.L.Wadhwa , High Voltage Engineering by, New Age Internationals (P) Limited, 1997.
4. Ravindra Arora, Wolfgang Mosch, High Voltage Insulation Engineering by, New Age International (P) Limited, 1995.
5. Mazen Abdel Salam, Hussein Anis, Ahdan El-Morshedy, Roshdy Radwan , Marcel Dekker

High Voltage Engineering, Theory and Practice.

EEPE32 DIGITAL SIGNAL PROCESSING

Externals: 60Marks L-T-P-C

Internals: 40Marks 3-0-0-3

Course Objectives: This course will develop student's knowledge in/on

- continuous-time (CT) and discrete-time (DT) signals
- discrete fourier transform (DFT), computational complexity of DFT and efficient implementation of DFT using fast fourier transform (FFT)
- specifying characteristics of frequency selective filters, design of linear-phase FIR filters
- classical analog butterworth & chebyshev filters, converting analog filter into equivalent digital filter to design digital IIR filters

Course Outcomes: At the end of the course the student will be able to:

- Represent signals mathematically in continuous and discrete-time, and in the frequency domain.
- Analyse discrete-time systems using z-transform.
- Understand the Discrete-Fourier Transform (DFT) and the FFT algorithms. Design digital filters for various applications.
- Apply digital signal processing for the analysis of real-life signals.

UNIT I: Discrete-time signals and systems (6 hours)

Discrete time signals and systems: Sequences; representation of signals on orthogonal basis; Representation of discrete systems using difference equations, Samplingand reconstruction of signals - aliasing; Sampling theorem and Nyquist rate.

UNIT II: Z-transform (6 hours)

Z-Transform, Region of Convergence, Analysis of Linear Shift Invariant systems using z-transform, Properties of z-transform for causal signals, Interpretation of stability in z-domain, Inverse z-transforms.

UNIT III: Discrete Fourier Transform (10 hours)

Frequency Domain Analysis, Discrete Fourier Transform (DFT), Properties of DFT, Convolutions of signals, Fast Fourier Transform Algorithm, Parseval's Identity, Implementation of Discrete Time Systems.

UNIT IV:Designof Digital filters (12 hours)

Designof FIR Digital filters: Windowmethod,Park-McClellan's method. Design of IIR Digital Filters: Butterworth, Chebyshev and Elliptic Approximations;Low-pass, Band-pass, Band- stop and High-pass filters. Effect of finite register length in FIR filter design. Parametric and non-parametric spectral estimation. Introduction to multi-rate signalprocessing.

UNIT V: Applications of Digital Signal Processing (6 hours)

Correlation Functions and Power Spectra, Stationary Processes, Optimal filtering using ARMA Model, Linear Mean-Square Estimation, Wiener Filter.

Text/Reference Books:

1. S. K. Mitra, " Digital Signal Processing: A computer based approach", McGraw Hill, 2011.
2. A.V. Oppenheim and R. W. Schafer, "Discrete Time Signal Processing" , Prentice Hall, 1989.
3. J. G. Proakis and D.G. Manolakis, " Digital Signal Processing: Principles, Algorithms And Applications", Prentice Hall, 1997.
4. L. R. Rabiner and B. Gold, "Theory and Application of Digital Signal Processing" , Prentice Hall, 1992.
5. J. R. Johnson, " Introduction to Digital Signal Processing" , Prentice Hall, 1992.
6. D. J. DeFatta, J. G. Lucas andW. S. Hodgkiss, " Digital Signal Processing" , John Wiley & Sons, 1988.

EEPE33 **CONTROL SYSTEM DESIGN**

Externals: 60Marks **L-T-P-C**

Internals: 40Marks **3-0-0-3**

Course Objectives:

- Analysis of properties of control systems, such as sensitivity, stability, controllability, tracking, in time and frequency domains; and
- Design of feedback controllers, such as PID, lead and lag compensators, pole placement designs, to meet desired system performance specifications.
- Understand various design specifications.
- Design controllers to satisfy the desired design specifications using simple controller structures (P, PI, PID, compensators).
- Design controllers using the state-space approach.

UNIT I: Design Specifications (6 hours)

Introduction to design problem and philosophy. Introduction to time domain and frequency domain design specification and its physical relevance. Effect of gain on transient and steady state response. Effect of addition of pole on system performance. Effect of addition of zero on system response.

UNIT II: (14 Hours) Design of Classical Control System in the time domain (8 hours)

Introduction to compensator. Design of Lag, lead lag-lead compensator in time domain. Feedback and Feed forward compensator design. Feedback compensation. Realization of compensators.

UNIT III: (14 hours)
Design of Classical Control System in frequency domain

Compensator design in frequency domain to improve steady state and transient response.
Feedback and Feed forward compensator design using bode diagram.
Design of PID controllers

Design of P, PI, PD and PID controllers in time domain and frequency domain for first, second and third order systems. Control loop with auxiliary feedback – Feed forward control.
UNIT IV: Control System Design in state space (8 hours)

Review of state space representation. Concept of controllability & observability, effect of pole zero cancellation on the controllability & observability of the system, pole placement design through state feedback. Ackerman’s Formula for feedback gain design. Design of Observer. Reduced order observer. Separation Principle.

UNIT V: Nonlinearities and its effect on system performance (4 hours)

Various types of non-linearities. Effect of various non-linearities on system performance.
Singular points. Phase plot analysis.

Text and Reference Books :

1. N. Nise, “ Control system Engineering”, John Wiley, 2000.
2. I. J. Nagrath and M. Gopal, “ Control system engineering”, Wiley, 2000.
3. M. Gopal, “ Digital Control Engineering”, Wiley Eastern, 1988.
4. K. Ogata, “ Modern Control Engineering”, Prentice Hall, 2010.
5. B. C. Kuo, “ Automatic Control system” , Prentice Hall, 1995.

J. J. D’Azzo and C. H. Houpis, “ Linear control system analysis and design (conventional and modern)”, McGraw Hill, 1995.

R. T. Stefani and G. H. Hostetter, “Design of feedback Control Systems”, Saunders College Pub, 1994.

EEPE41 **ARTIFICIAL NEURAL NETWORKS AND FUZZY SYSTEMS**

Externals: 60Marks **L-T-P-C**

Internals: 40Marks **3-0-0-3**

Course Objectives:

- To introduce the basics of Neural Networks and its architectures.
- To introduce the Fuzzy sets and Fuzzy Logic system components
- To deal with the applications of Neural Networks and Fuzzy systems

Course Outcomes: At the end of the course the student will be able to:

- To understand artificial neural network models and their training algorithms
- To understand the concept of fuzzy logic system components, fuzzification and defuzzification
- Design the layout of Gas Insulated substations and to know the concepts of insulation coordination.

UNIT I: Introduction To Neural Networks and Essentials of Artificial Neural Networks(9 Hours)

Introduction, Humans and Computers, Organization of the Brain, Biological Neuron, Biological and Artificial Neuron Models, Hodgkin-Huxley Neuron Model, Integrate-and-Fire Neuron Model, Spiking Neuron Model, Characteristics of ANN, McCulloch-Pitts Model, Historical Developments, Potential Applications of ANN.

Essentials of Artificial Neural Networks

Artificial Neuron Model, Operations of Artificial Neuron, Types of Neuron Activation Function, ANN Architectures, Classification Taxonomy of ANN – Connectivity, Neural Dynamics (Activation and Synaptic), Learning Strategy (Supervised, Unsupervised, Reinforcement), Learning Rules, Types of Application.

UNIT II: Feed forward and Multilayer Feed forward neural networks(9 Hours)

Single Layer Feed Forward Neural Networks: Introduction, Perceptron Models: Discrete, Continuous and Multi-Category, Training Algorithms: Discrete and Continuous Perceptron Networks, Perceptron Convergence theorem, Limitations of the Perceptron Model, Applications.

Multilayer Feed forward Neural Networks

Credit Assignment Problem, Generalized Delta Rule, Derivation of Back propagation (BP)

Training, Summary of Back propagation Algorithm, Kolmogorov Theorem, Learning Difficulties and Improvements.

UNIT III: (8 Hours)

Associative Memories

Paradigms of Associative Memory, Pattern Mathematics, Hebbian Learning, General Concepts of Associative Memory (Associative Matrix, Association Rules, Hamming Distance, The Linear Associator, Matrix Memories, Content Addressable Memory).

Bidirectional Associative Memory (BAM) Architecture, BAM Training Algorithms

Storage and Recall Algorithm, BAM Energy Function, Proof of BAM Stability Theorem. Architecture of Hopfield Network: Discrete and Continuous versions, Storage and Recall Algorithm, Stability Analysis, Capacity of the Hopfield Network.

UNIT IV: Classical And Fuzzy Sets(7 Hours)

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

UNIT V: Fuzzy Logic System (7 Hours)

Fuzzification, Membership value assignment, development of rule base and decision making system, Defuzzification to crisp sets, Defuzzification methods.

Text books:

1. Rajasekharan and Pai, Neural Networks, Fuzzy logic, Genetic algorithms: synthesis and applications– PHI Publication.
2. Satish Kumar , Neural Networks, TMH, 2004.

Reference books:

1. James A Freeman and Davis Skapura, Neural Networks, Pearson Education, 2002.
2. Simon Hakins, Neural Networks, Pearson Education.
3. C..Eliasmith and Ch. Anderson, Neural Engineering, PHI.

EEPE43 **LINE-COMMUTATED AND ACTIVE PWM RECTIFIERS**

Externals: 60Marks **L-T-P-C**

Internals: 40Marks **3-0-0-3**

Course Outcomes: At the end of the course the student will be able to:

- Understand the operation of line-commutated rectifiers – 6 pulse and multi-pulse configurations.
- Understand the operation of PWM rectifiers – operation in rectification and regeneration modes and lagging, leading and unity power factor mode.

UNIT I: Multi-Pulse converter(6 Hours)

Review of transformer phase shifting, generation of 6-phase ac voltage from 3-phase ac, 6- pulse converter and 12-pulse converters with inductive loads, steady state analysis, commutation overlap, notches during commutation.

UNIT II: Single-phase ac-dc single-switch boost converter

Review of dc-dc boost converter, power circuit of single-switch ac-dc converter, steady state analysis, unity power factor operation, closed-loop control structure.

UNIT III: Ac-dc bidirectional boost converter

Review of 1-phase inverter and 3-phase inverter, power circuits of 1-phase and 3-phase ac-dc boost converter, steady state analysis, operation at leading, lagging and unity power factors. Rectification and regenerating modes. Phasor diagrams, closed-loop control structure.

UNIT IV: Isolated single-phase ac-dc flyback converter-I

Dc-dc flyback converter, output voltage as a function of duty ratio and transformer turns ratio.

UNIT V: Isolated single-phase ac-dc flyback converter-I

Power circuit of ac-dc flyback converter, steady state analysis, unity power factor operation, closed loop control structure.

Text / References:

1. G. De, “Principles of Thyristorised Converters”, Oxford & IBH Publishing Co, 1988.
2. J.G. Kassakian, M. F. Schlecht and G. C. Verghese, “Principles of Power Electronics”, Addison- Wesley, 1991.
3. L. Umanand, “ Power Electronics: Essentials and Applications”, Wiley India, 2009.
4. N. Mohan and T. M. Undeland, “ Power Electronics: Converters, Applications and Design” , John Wiley & Sons, 2007.
5. R. W. Erickson and D. Maksimovic, “Fundamentals of Power Electronics”, Springer Science & Business Media, 2001.

EEPE51 **HVDC TRANSMISSION**

Externals: 60Marks **L-T-P-C**

Internals: 40Marks **3-0-0-3**

Course objectives:

- To understand the concept, planning of DC power transmission and comparison with AC Power transmission.
- To analyze HVDC converters.
- To study about the HVDC system control.
- To analyze harmonics and design of filters.
- To model and analysis the DC system under study state.

Course Outcomes: At the end of the course the student will be able to:

- Identify significance of DC over AC transmission system, types and application of HVDC links in practical power systems.
- Understand operating principles of HVDC systems and control aspects.
- Model AC/DC system and apply protection for HVDC system against transient overvoltage and over currents

UNIT I: Basic Concepts (7 Hours)

Economics & Terminal equipment of HVDC transmission systems: Types of HVDC Links Apparatus required for HVDC Systems**,** Comparison of AC & DC Transmission, Application of DC Transmission System Planning & Modern trends in D.C. Transmission.

UNIT II: HVDC Converters (8 Hours)

Analysis of HVDC Converters
Choice of Converter configuration analysis of Graetz circuit characteristics of 6Pulse&12Pulseconverters Cases of two 3phase converters in star star mode their performance.
Converter & HVDC System Control
Principle of DC Link Control, Converters Control Characteristics, Firing angle control, Current and extinction angle control, Effect of source inductance on the system; Starting and stopping of DC link; Power Control**.**

UNIT III: Reactive Power Control In HVDC and Power Flow Analysis In AC/DC Systems (9 Hours)

Reactive Power Control In HVDC

Reactive Power Requirements in steady state-Conventional control strategies- Alternate control strategies-sources of reactive power-AC Filters shunt capacitors- synchronous condensers.

Power Flow Analysis In AC/DC Systems

Modeling of DC Links - DC Network - DC Converter - Controller Equations Solution of DC load flow P.U. System for D.C quantities- solution of AC-DC Power flow-Simultaneous method-Sequential method.

UNIT IV: Converter Fault & Protection *(7 Hours)*

Converter faults, protection against over current and over voltage in converter station, surge arresters, smoothing reactors, DC breakers, Audible noise-space charge field-corona effects on DC lines-Radio interference.

UNIT V: Harmonics and Filters (8 Hours)

Harmonics

Generation of Harmonics Characteristics of harmonics, calculation of AC Harmonics, Non-Characteristics of harmonics, adverse effects of harmonics Calculation of voltage & Current harmonics

Effect of Pulse number on harmonics

Filters

Types of AC filters, Design of Single tuned filters Design of High pass filters.

Text Books:

1. K.R. Padiyar"HVDC Power Transmission Systems: Technology and system Interactions" New Age International(P) Limited, and Publishers.
2. S.S. Rao"EHVAC and HVDC Transmission Engineering and Practice"

Reference Books:

1. E.W. Kimbark "HVDC Transmission Direct Current Transmission" John Wiley & Sons.
2. S.Kamakshaiah and V.Kamaraju, 'HVDC Transmission', 1 st Edition, Tata McGraw Hill, 2011.
3. E.Uhlmann"Power Transmission by DirectCurrent" B.S.Publications

EEPE52 **SWITCH MODE POWER SUPPLIES**

Externals: 60Marks **L-T-P-C**

Internals: 40Marks **3-0-0-3**

Course Objectives:

- This course introduces the basic concepts of switched mode power supplies, working of SMPS and different types of converters.
- The course discusses multiple output Fly back SMPS, uses of semiconductors in switched mode topology and different types of switched mode variable power supplies.

Course Outcomes: At the end of the course the student will be able to:

- Know the operation of SMPS, importance of semiconductors in SMPS and different types of SMPS
- Analyze different types of converters, the process of Rectification and different types of switched mode variable power supplies
- Switching devices - ideal and real characteristics, control, drive and protection.
- Reactive circuit elements - their selection and design.
- Switching power converters - circuit topology, operation, steady-state model, dynamic model.
- Analysis, modeling and performance functions of switching power converters.
- Review of linear control theory.
- Closed-loop control of switching power converters.
- Sample designs and construction projects.

UNIT I: Reactive circuit elements - their selection and design.: Introduction to DC-DC

converter, Diode Controlled Switches, Reactive components: Inductor, Transformer, Capacitor, Issues related to switches, Energy storage – Capacitor, Energy storage – inductor

UNIT II: Switched Mode Power Conversion (10 Hours)

Equivalent circuit model of the non-isolated DC-DC converters. Isolated converters (forward, Fly back).

Multiple Output Fly back Switch Mode Power Supplies *(6 Hours)*

Introduction, operating Modes, operating principles, Direct off line Flyback Switch Mode Power

Supplies, Fly back converter, snubber network, Problems.

UNIT III: Using Power Semiconductors in Switched Mode Topologies (8 Hours)
Half-Bridge and Full Bridge
Converters, Push-Pull Converter and SMPS with multiple outputs. Choice of switching frequency, The Power Supply Designer's Guide to High Voltage Transistors, Base Circuit Design for High Voltage Bipolar Transistors in Power Converters, Isolated Power Semiconductors for High Frequency Power Supply Applications

UNIT IV: Rectification (7 Hours)

Explanation, Advantages and disadvantages, SMPS and linear power supply comparison, Theory of operation , Input rectifier stage, Inverter stage, Voltage converter and output rectifier, Regulation, An Introduction to Synchronous Rectifier Circuits using Power MOS Transistors

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UNIT V: Concept of Zero Voltage switching (ZVS) and Zero current switching (ZCS) (6 Hours)

Resonant Power Supplies;
An Introduction to Resonant Power Supplies, Resonant Power Supply Converters - The Solution for Mains Pollution Problems.

Text Books:

1. "Switch Mode Power Supplies" by Keith H. Billings Taylor Morey- Tata McGraw-Hill Publishing Company, 3rd edition.
2. "Switch Mode Power Supplies", Robert W. Erickson.

Reference Books:

1. Switching Power Supplies A-Z, Second Edition- Sanjaya Maniktala.
2. Steven M. Sandler, Switch Mode Power Supplies, Tata McGraw Hill.

EEPE53 **SMART GRID**

Externals: 60Marks	**L-T-P-C**
Internals: 40Marks	**3-0-0-3**

Course Objectives:

- This course introduces the basic concepts of a Smart Grid, different types of constraints and different types of communication technologies for Smart Grid
- It introduces different types of Security systems for the Smart grid
- This course discusses the smart metering and distribution system modeling

Course Outcomes: At the end of the course the student will be able to:

- Understand the background for Smart Grid and have knowledge about important Terminologies
- Know about challenges and possibilities related to Smart Meters
- Analyze and perform basic design of Smart Grid electric power systems
- The course discusses the interaction between the power grid and Flexible resources and Smart Meters

UNIT I: The Smart Grid (8 Hours)

Introduction, Ageing Assets and Lack of Circuit Capacity, Thermal Constraints, Operational Constraints, Security of Supply, National Initiatives, Early Smart Grid Initiatives, Active Distribution Networks, Virtual Power Plant, Other Initiatives and Demonstrations, Overview of The Technologies Required for The Smart Grid.

UNIT II: Communication Technologies (10 Hours)

Data Communications: Introduction, Dedicated and Shared Communication Channels, Switching Techniques, Circuit Switching, Message Switching, Packet Switching, Communication Channels, Wired Communication, Optical Fibre, Radio Communication, Cellular Mobile Communication, Layered Architecture and Protocols, The ISO/OSI Model, TCP/IP Communication Technologies: IEEE 802 Series, Mobile Communications, Multi Protocol Label Switching, Power line Communication, Standards for Information Exchange, Standards For Smart Metering, Modbus, DNP3, IEC61850

UNIT III: Information Security For The Smart Grid (8 Hours)

Introduction, Encryption and Decryption, Symmetric Key Encryption, Public Key Encryption, Authentication, Authentication Based on Shared Secret Key, Authentication Based on Key Distribution Center, Digital Signatures, Secret Key Signature, Public Key Signature, Message Digest, Cyber Security Standards, IEEE 1686: IEEE Standard for Substation Intelligent Electronic Devices(IEDs) Cyber Security Capabilities, IEC 62351: Power Systems Management And Association Information Exchange – Data and Communication Security.

UNIT IV: Smart Metering And Demand Side Integration ***(8 Hours)***

Introduction, smart metering – evolution of electricity metering, key components of smart metering, smart meters: an overview of the hardware used – signal acquisition, signal conditioning, analogue to digital conversion, computation, input/output, and communication.
Communication infrastructure and protocols for smart metering- Home area network, Neighbourhood Area Network, Data Concentrator, meter data management system, Protocols for communication. Demand Side Integration- Services Provided by DSI, Implementation of DSI, Hardware Support, Flexibility Delivered by Prosumers from the Demand Side, System Support from DSI.

UNIT V: Transmission And Distribution Management Systems ***(8 Hours)***

Data Sources, Energy Management System, Wide Area Applications, Visualization Techniques, Data Sources and Associated External Systems, SCADA, Customer Information System, Modelling and Analysis Tools, Distribution System Modelling, Topology Analysis, Load Forecasting, Power Flow Analysis, Fault Calculations, State Estimation, Applications, System Monitoring, Operation, Management, Outage Management System, Energy Storage Technologies, Batteries, Flow Battery, Fuel Cell and Hydrogen Electrolyser, Flywheels, Superconducting Magnetic Energy Storage Systems, Supercapacitors.

Text Books:

1. Smart Grid, Janaka Ekanayake, Liyanage, Wu, Akihiko Yokoyama, Jenkins, Wiley Publications, 2012.

2. Smart Grid:Fundamentals of Design and Analysis.James Momoh,Wiley,IEEE Press.,2012.

EEPE62 **ELECTRICAL AND HYBRID VEHICLES**

Externals: 60Marks	**L-T-P-C**
Internals: 40Marks	**3-0-0-3**

Course Outcomes: At the end of the course the student will be able to:

- Understand the models to describe hybrid vehicles and their performance.
- Understand the different possible ways of energy storage.
- Understand the different strategies related to energy storage systems.

UNIT I: Introduction to Conventional Vehicles and Hybrid Electric Vehicles :(10 hours)

Conventional Vehicles: Basics of vehicle performance, vehicle power source characterization, transmission characteristics, mathematical models to describe vehicle performance.
Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies.

UNIT II: Hybrid Electric Drive-trains: (6 hours)

Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis.

UNIT III: Electric Trains (10 hours)

Electric Drive-trains: Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis. Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives, configuration and control of Permanent Magnet Motor drives, Configuration and control of Switch Reluctance Motor drives, drive system efficiency.

UNIT IV: Energy Storage (9 hours)

Energy Storage: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices. Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE)

UNIT V: Energy Management Strategies (7 hours)

Energy Management Strategies: Introduction to energy management strategies used in hybrid and electric vehicles, classification of different energy management strategies, comparison of different energy management strategies, implementation issues of energy management strategies.
Case Studies: Design of a Hybrid Electric Vehicle (HEV), Design of a Battery Electric Vehicle (BEV).

Text / References:

1. C. Mi, M. A. Masrur and D. W. Gao, " Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives", John Wiley & Sons, 2011.
2. S. Onori, L. Serrao and G. Rizzoni, " Hybrid Electric Vehicles: Energy Management Strategies", Springer, 2015.
3. M. Ehsani, Y. Gao, S. E. Gay and A. Emadi, " Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design", CRC Press, 2004.
4. T. Denton, "Electric and Hybrid Vehicles", Routledge, 2016.

EEPE63 **POWER QUALITY AND FACTS**

Externals: 60Marks **L-T-P-C**

Internals: 40Marks **3-0-0-3**

Course Objectives:

- This course mainly focuses on the various power quality issues, monitoring and the enhancement of the power quality.
- To understand the concept of flexible AC transmission and the associated problems.
- To review the static devices for series and shunt control.
- To study the operation of controllers for enhancing the transmission capability.

Course Outcomes: At the end of the course the student will be able to:

- Understand the characteristics of ac transmission and the effect of shunt and series reactive compensation.
- Understand the working principles of FACTS devices and their operating characteristics.
- Understand the basic concepts of power quality.
- Understand the working principles of devices to improve power quality.

UNIT I: Transmission Lines and Series/Shunt Reactive Power Compensation(10 hours)

Analysis of uncompensated AC transmission lines. Passive Reactive Power Compensation. Shunt and series compensation at the mid-point of an AC line. Comparison of Series and Shunt Compensation.

Thyristor-based Flexible AC Transmission Controllers (FACTS)

Description and Characteristics of Thyristor-based FACTS devices: Static VAR Compensator (SVC), Thyristor Controlled Series Capacitor (TCSC), Thyristor Controlled Braking Resistor and Single Pole Single Throw (SPST) Switch. Configurations/Modes of Operation, Harmonics and control of SVC and TCSC. Fault Current Limiter.

UNIT II: Voltage Source Converter based (FACTS) controllers (8 hours)

Voltage Source Converters (VSC): Six Pulse VSC, Multi-pulse and Multi-level Converters, Pulse-Width Modulation for VSCs. Selective Harmonic Elimination, Sinusoidal PWM and Space Vector Modulation. STATCOM: Principle of Operation, Reactive Power Control: Type I and Type II controllers, Static Synchronous Series Compensator (SSSC) and Unified Power Flow Controller (UPFC): Principle of Operation and Control. Working principle of Interphase

Power Flow Controller. Other Devices: GTO Controlled Series Compensator. Fault Current Limiter.

UNIT III: Application of FACTS (4 hours)

Application of FACTS devices for power-flow control and stability improvement. Simulation example of power swing damping in a single-machine infinite bus system using a TCSC. Simulation example of voltage regulation of transmission mid-point voltage using a STATCOM.

UNIT IV: Power Quality Problems in Distribution Systems (4 hours)

Power Quality problems in distribution systems: Transient and Steady state variations in voltage and frequency. Unbalance, Sags, Swells, Interruptions, Wave-form Distortions: harmonics, noise, notching, dc-offsets, fluctuations. Flicker and its measurement. Tolerance of Equipment: CBEMA curve.

UNIT V: DSTATCOM (14 hours)

Reactive Power Compensation, Harmonics and Unbalance mitigation in Distribution Systems using DSTATCOM and Shunt Active Filters. Synchronous Reference Frame Extraction of Reference Currents. Current Control Techniques in for DSTATCOM.

Dynamic Voltage Restorer and Unified Power Quality Conditioner

Voltage Sag/Swell mitigation: Dynamic Voltage Restorer – Working Principle and Control Strategies. Series Active Filtering. Unified Power Quality Conditioner (UPQC): Working Principle. Capabilities and Control Strategies.

Text/References:

1. N. G. Hingorani and L. Gyugyi, “ Understanding FACTS: Concepts and Technology of FACTS Systems”, Wiley-IEEE Press, 1999.
2. K. R. Padiyar, “ FACTS Controllers in Power Transmission and Distribution”, New Age International (P) Ltd. 2007.
3. T. J. E. Miller, “ Reactive Power Control in Electric Systems”, John Wiley and Sons, New York, 1983.
4. R. C. Dugan, “Electrical Power Systems Quality”, McGraw Hill Education, 2012.
5. G. T. Heydt, “Electric Power Quality” , Stars in a Circle Publications, 1991