# Department of Electrical Engineering
## M Tech in High Voltage Engineering (EEE)
## **Brief & detailed Syllabus**

### MA6003: Mathematical Methods for Power Engineering

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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Vector spaces, Linear transformations, Matrix representation of linear transformation, Eigen values and Eigen vectors of linear operator. Linear Programming Problems, Simplex Method, Duality, Non Linear Programming problems, Unconstrained Problems ,Search methods, Constrained Problems , Lagrange method ,Kuhn-Tucker conditions. Random Variables, Distributions, Independent Random Variables, Marginal and Conditional distributions, Elements of stochastic processes mming Problems, Simplex Method, Duality, Non Linear Programming

### EE6301: Power Electronic Circuits

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

D.C. chopper circuits, Line Frequency Diode Rectifiers, Three Phase half wave rectifier with resistive load. Three phase full wave rectifier. Line Frequency Phase-Controlled Rectifiers and Inverters. Single Phase Input Line Current Harmonics and Power Factor- Inverter Mode of Operation - Three Phase. Half Wave Controlled rectifier with RL Load. Half Controlled Bridge with RL Load. Fully Controlled Bridge with RL Load. Input Side Current Harmonics and Power Factor - Dual Converters Switch-Mode dc-ac Inverters. Basic Concepts. Single Phase Inverters. PWM Principles. Sinusoidal Pulse Width Modulation in Single Phase Inverters. Three Phase Inverters -Three Phase Square Wave /Stepped Wave Inverters. Three Phase SPWM Inverters Output Filters. DC Side Current Converters for Static Compensation. Standard Modulation Strategies Multi-Level Inverters Space Vector Modulation Current Regulated Inverter

### EE6501: High Voltage Engineering

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**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Generation and measurement of high voltage AC, DC and Impulse voltages and currents. Detailed study of solid, liquid and gaseous insulation and its breakdown phenomena. Application of nanofilled material as electrical insulation for high voltage power apparatus.

## EE6503 Power System Transients

| L | T | P | C |
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**Pre-requisite: Nil**
**Total hours: 42 Hrs**

Electrical transients- Switching transients-Laplace transform method of solving-digital computation-overvoltages-Lightning, switching and temporary overvoltages-travelling waves-Insulation coordination-protective devices.

## EE6591 High Voltage Laboratory

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Experiments on measurement of HVAC and HVDC by sphere gap, chubb and fortescue method, voltage divider method and AC breakdown studies on solid and liquid insulation. Simulation of field for different electrode arrangements

## EE 6502: Computational Electromagnetics

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

The Maxwell equations. Time-domain methods: finite differences and finite elements. Frequency-domain methods: The method of moments, finite elements. High frequency methods: Geometrical optics, diffraction and multipole methods. Areas of application.

## EE6504: Physics of Dielectrics

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**Pre-requisite: EE 6501 High Voltage Engineering**
**Total hours: 42 Hrs.**

Dielectrics and electrical insulation used in HV Power apparatus, behaviour of insulators under time varying electric field, mechanism of breakdown in solid dielectrics, Ageing theory and accelerated tests for determining the life, polymers as insulation, nanodielectrics, design of insulation systems

## EE6506: EHV Power Transmission

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Introduction to EHV AC Transmission- Calculations of line and ground parameters- Corona- factors affecting corona. Audible noise - radio interference, limits for radio interference fields - Theory of reactive power control- different reactive power compensation methods- HVDC transmission-HVDC link.

## EE6201: Computer Methods in Power Systems

| L | T | P | C |
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**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Power flow analysis- Sparsity Oriented and Optimal Ordering-Fault Analysis-Power System Optimization-Optimal Load flow solution- Optimum reactive power dispatch-Scheduling of hydrothermal systems-AI Techniques applied to power Systems- Power system security-Contingency analysis-state estimation.

## EE6222: Power Quality

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Power quality measures and standards-IEEE guides, standards and recommended practices, Harmonics--important harmonic introducing devices -effect of power system harmonics on power system equipment and loads. - Modeling of networks and components under non-sinusoidal conditions, power quality problems created by drives - Power factor improvement- Passive Compensation - Active Power Factor Correction - Single Phase APFC, Three Phase APFC and Control Techniques, static var compensators-SVC and STATCOM - Active Harmonic Filtering-Dynamic Voltage Restorers for sag, swell and flicker problems. - Grounding and wiring-introduction

## EE6308: FACTS and Custom Power

| L | T | P | C |
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**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Steady-state and dynamic problems in AC systems –Power flow control - Benefits of FACTS Transmission line compensation- Uncompensated line -shunt and series compensation -Reactive power compensation – shunt and series compensation principles VAr Compensators –Static shunt compensators: SVC and STATCOM -Static series compensation: TSSC, SSSC - TCVR and TCPAR-Operation and Control - GCSC,TSSC, TCSC and Static synchronous series compensators and their control - Unified Power Flow Controller: Modelling and analysis of FACTS Controllers – simulation of FACTS controllers -Power quality problems in distribution systems, mitigation of harmonics, passive filters, active filtering – shunt , series and hybrid and their control - power line conditioners-IEEE standards on power quality.

## EE 6505: High Voltage DC Transmission

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Evolution of HVDC systems, comparison of HVAC and HVDC transmission systems, components of HVDC transmission system, analysis of HVDC converters, HVDC control, mal-operation and protection of converters, filter design, AC/DC load flow and stability analysis, multi-terminal HVDC, different application of HVDC system, advances in HVDC systems.

## EE6426: Distribution Systems Management and Automation

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Distribution Automation System, Integration of Distributed Generation and Custom Power components in distribution systems, Electrical System Design, Electrical Safety and Earthing Practices, Communication Systems for Control and Automation, Power Quality and Custom Power, Deregulated Systems.

## EE6122: Biomedical Instrumentation

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Fundamental of Biomedical Instrumentation – origin of bio potentials – biomedical transducers – bio signals ,ECG,EMG,EEG etc – measurement of cardiac output, blood flow, blood pressure etc – oximeters- measurements on pulmonary system – blood gas analyzers – audiometers – patient safety – lasers in medicine – X –ray applications – ultrasound in medicine – pacemakers – defibrillators – electrotherapy – hemodialysis – ventilators –radiotherapy

## EE6103: Applied Instrumentation

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Generalized performance characteristics of measuring systems-general static and dynamic characteristics- mathematically models-general concepts of transfer functions related to instrumentation system. Response of general form of instruments to different types of inputs like periodic, transient and random signals, their characteristics etc. Study, analysis etc of modulation and demodulation problems of instrumentation systems. Design considerations of instrumentation systems.

## EE6428: SCADA Systems and Applications

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Introduction to SCADA, Monitoring and supervisory functions, SCADA applications in Utility Automation, SCADA System Components, RTU, IED, PLC, Communication Network, SCADA Server, SCADA/HMI Systems, Various SCADA architectures, single unified standard architecture - IEC 61850, SCADA Communication, open standard communication protocols.

## EE6129: Artificial Neural Networks and Fuzzy Systems

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Biological foundations - ANN models - network architectures - learning processes - single layer and multilayer perceptures - least mean square algorithm - back propagation algorithm - applications in engineering problems - fuzzy sets - fuzzy set operations - membership functions - fuzzy to crisp conversion - fuzzification and defuzzification methods -fuzzification and defuzzification methods - applications in engineering problems - fuzzy control systems - fuzzy logic controllers with examples - special forms of fuzzy logic models - classical fuzzy control problems - image processing - adaptive fuzzy systems - hybrid systems.

## EE6304: Advanced Digital Signal Processing

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Discrete time signals, systems and their representations - Discrete Fourier series- Discrete Fourier transform- Z- transform- Computation of DFT Digital filter design and realization structures Basic IIR and FIR filter realization structures- Signal flow graph representations Quantization process and errors- Coefficient quantisation effects in IIR and FIR filters- A/D conversion noise- Arithmetic round-off errors- Dynamic range scaling- Overflow oscillations and zero input limit cycles in IIR filters Statistical signal processing Linear Signal Models -Power spectrum estimation- Spectral analysis of deterministic signals . Estimation of power spectrum of stationary random signals-Optimum linear filters-Optimum signal estimation-Mean square error estimation-Optimum FIR and IIR filters.fuzzy systems - hybrid systems.

## EE6323: Digital Simulation of Power Electronic Systems

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Principles of Modeling Power Semiconductor Devices - Macromodels versus Micromodels - Modelling of Control Circuits for Power Electronic Switches. Computer - Review of Graph Theory as applied to Electrical Networks - Circuit Analysis Software MicroSim PSpice A/D - Statistical Analyses - Simulation Examples of Power Electronic systems.-MicroSim PSpice A/D - MATLAB SIMULINK in Power system.-Design Creation and Simulation with SaberDesigner - Analysing waveforms with SaberScope

## EE6422: Engineering Optimization

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Concepts of optimization, Classical Optimization Techniques, Linear programming, dual simplex method, Minimum cost flow problem, Network problems-transportation, assignment & allocation, Nonlinear programming, Unconstrained optimization, Constrained optimization, Dynamic programming, Genetic algorithms, optimization using software packages.

## NS 6101: Structure of Nanomaterials

| L | T | P | C |
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Classification of nanostructures, nanoscale architecture, fundamental structure, chemistry, property relationships in nanomaterials and nanomaterial systems. Electronic properties of atoms and solids, the isolated atom, bonding between atoms, giant molecular solids. Nanocrystalline materials, nanocomposities. Nanoscale x-ray - electron and neutron diffraction techniques,Scanning electron microscopy, Transmission electron microscopy , Atomic force microscopy (AFM), Scanning tunneling microscopy (STM).

## NS 6112: Experimental Techniques in Nanotechnology

| L | T | P | C |
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Statistical principles for design-of-experiment methods as applied to nanomaterials Elementary ideas of blocking, general principles of linear model analysis. Experimental techniques for temperature measurement – Characterization techniques in nanotechnology - Micorscopy - Spectroscopic Methods

## NS 6124: Computational Nanotechnology

| L | T | P | C |
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Need for discrete computations, classical mechanics – Hamilton's principle and Lagrange's equations, statistical mechanics – quantum states, ensembles, partition function, equipartition theorem and Maxwell distribution of molecular speeds, Atomistic simulation techniques – Molecular Dynamics and Monte Carlo methods, Mesoscopic methods – Lattice Boltzmann method and Dissipative Particle Dynamics, Introduction to Multiscale methods

## EE6121: Data Acquisition & Signal Conditioning

| L | T | P | C |
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**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Data Acquisition Systems(DAS) - Objectives - General configurations - Transducers - Signal Conditioning - Instrumentation amplifiers - Noise Reduction Techniques in Signal Conditioning-Transmitters -Piezoelectric Couplers- Nyquist's Sampling Theorem- classification and types of filters - Design of Filters- Butterworth Approximation-Narrow Bandpass and Notch Filters and their application in DAS-Analog-to-Digital Converters(ADC)-Multiplexers and demultiplexers -Digital-to-Analog Conversion(DAC)- Data transmission systems- Modulation techniques and systems-Telemetry systems- Study of a representative DAS Board-Interfacing issues with DAS Boards-Software Drivers, Virtual Instruments, Modular Programming Techniques-Bus standard for communication between instruments - Software Design Strategies for DAS.

## EE6221: Distributed Generation

| L | T | P | C |
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**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Principle of renewable energy systems-technical and social implications- solar energy conversion methods- analysis-economics-applications- solar thermal power generation, Direct energy conversion- Photovoltaic system- Lighting and water pumping applications. Biofuels- Fuel cells-MHD. Wind energy- wind mills. applications- economics of wind power. OTEC-Tidal power sources and applications. Micro and mini hydel power. Hybrid Energy Systems.

## EE6302: Advanced Power Electronic Circuits

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Special Inverter Topologies -Series Inverters. Switched Mode Rectifier - Single phase and three phase boost type APFC and control, Three phase utility interphases and control-Buck, Boost, Buck-Boost SMPS Topologies . modes of operation –Push-Pull and Forward Converter Topologies - Voltage Mode Control.-Half and Full Bridge Converters . Flyback Converter. Introduction to Resonant Converters. Load Resonant Converter. Zero Voltage Switching Clamped Voltage Topologies. Resonant DC Link Inverters with Zero Voltage Switching. High Frequency Link Integral Half Cycle Converter.

## EE6508: High Voltage Testing Techniques

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Objectives of high voltage testing, Determination of probability values - Distribution function of a measured quantity, confidence limits, Testing of insulators, bushings, air break switches, isolators, Dynamic properties of dielectrics-dielectric loss and capacitance measurement, Dimensions of High voltage laboratory, equipment - fencing, earthing and shielding - circuits for high voltage experiments.

## EE6507: High Voltage Power Transformers and Circuit Breakers

| L | T | P | C |
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**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Power Transformer principle and equivalent circuit, Impedance characteristics, short circuit forces, surge phenomenon, Condition monitoring and diagnosis, HV circuit breakers, testing of circuit breakers.

## EE6204: Digital Protection of Power Systems

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Protective Relaying - Classification – numerical; Basic elements of digital protection –signal conditioning- FFT and Wavelet based algorithms: Relay Schematics and Analysis- Protection of Power System Equipment - Generator, Transformer, Transmission Systems, Busbars, Motors; Pilotwire and Carrier Current Schemes, Integrated and multifunction protection schemes -SCADA based protection systems- FTA, Testing of Relays.

## EE6509: Electromagnetic Interference and Compatibility

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**
Electromagnetic compatibility requirements and principles, non-ideal component behaviour, EMI measurements, EMC standard and regulations conducted and EMI control methods and fixes, EMC design and interconnection techniques.

## EE 6510: Pulsed Power Engineering

| L | T | P | C |
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**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

Introduction to pulsed power systems, Insulation and breakdown, Computer simulations, High power switches, Applications, High voltage hazards and accidents.

## EE6401: Energy Auditing & Management

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs**

Energy auditing: Types and objectives-audit instruments, Energy efficient /high efficient Motors-Case study; Load Matching and selection of motors, Reactive Power management-Capacitor Sizing-Degree of Compensation-Capacitor losses-Location-Placement-Maintenance, case study, Cogeneration-Types and Schemes-Optimal operation of cogeneration plants-case study, Energy conservation in Lighting Schemes, VFD, Energy conservation measures in Gysers, Transformer, Feeder, Pumps and Fans

## MA6003: Mathematical Methods for Power Engineering

| L | T | P | C |
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**Pre-requisite-Nil**
**Total hours: 42 Hrs.**

**Module 1**: **Linear Algebra (10 hours)**
Vector spaces, subspaces, Linear dependence, Basis and Dimension, Linear transformations, Kernels and Images , Matrix representation of linear transformation, Change of basis, Eigen values and Eigen vectors of linear operator.

**Module 2: Optimisation Methods I (11 hours)**
Mathematical formulation of Linear Programming Problems, Simplex Method, Duality in Linear Programming, Dual Simplex method.

**Module 3: Optimisation Methods II (10 hours)**
Non Linear Programming preliminaries, Unconstrained Problems ,Search methods , Fibonacci Search, Golden Section Search, Constrained Problems , Lagrange method ,Kuhn-Tucker conditions .

**Module 4: Operations on Random Variables (11 hours)**
Random Variables, Distributions and Density functions, Moments and Moment generating function, Independent Random Variables, Marginal and Conditional distributions, Conditional Expectation, Elements of stochastic processes, Classification of general stochastic processes.

**References**
1. Kenneth Hoffman and Ray Kunze, Linear Algebra, 2nd Edition, PHI, 1992.
2. Erwin Kreyszig, Introductory Functional Analysis with Applications, John Wiley & Sons, 2004.
3. Irwin Miller and Marylees Miller, John E. Freund's Mathematical Statistics, 6th Edn, PHI, 2002.
4. J. Medhi, Stochastic Processes, New Age International, New Delhi, 1994
5. A Papoulis, Probability, Random Variables and Stochastic Processes, 3rd Edition, McGraw Hill, 2002
6. John B Thomas, An Introduction to Applied Probability and Random Processes, John Wiley, 2000
7. Hillier F S and Liebermann G J, Introduction to Operations Research, 7th Edition, McGraw Hill, 2001
8. Simmons D M, Non Linear Programming for Operations Research, PHI, 1975

## EE6501: High Voltage Engineering

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

**Module 1: (11 hours)**

Requirements of HV generation in laboratory, Generation of High voltages, AC voltages: cascade transformers-series resonance circuits; DC voltages: voltage doubler-cascade circuits-electrostatic machines
Generation of Impulse voltages and currents: single stage and multistage circuits-wave shaping-tripping and control of impulse generators Generation of switching surge voltage and impulse currents

**Module 2: (11 hours)**

Measurement of high voltages and currents-DC, AC and impulse voltages and currents-DSO-electrostatic and peak voltmeters-sphere gaps-factors affecting measurements-potential dividers(capacitive and resistive)-series impedance ammeters-rogowski coils-hall effect generators Digital techniques in HV measurements, Measurement of electric field.

**Module 3: (9 hours)**

Insulation materials and -systems: insulation systems in practice, dielectric losses, ageing and life expectancy.
Classifications of insulation based on temperature withstand limits. Materials for outdoor insulation. Applications of nanofilled materials for outdoor and indoor insulation.

**Module 4: (11 hours)**

Introduction to solid, liquid and gaseous dielectrics. Breakdown in gas and gas mixtures-breakdown in uniform and non uniform fields-Paschens law-Townsends criterion-streamer mechanism-corona discharge-breakdown in electro negative gases. Breakdown in liquid dielectrics-suspended particle mechanism. Breakdown in solid dielectrics - intrinsic, streamer and thermal breakdown.

**References**


1. M. S. Naidu, V. Kamaraju, "High Voltage Engineering", McGraw-Hill, 1995.
2. M. Khalifa, "High Voltage Engineering: Theory and Practice", Dekker, 1990.
3. Kuffel and Zaengal , “High Voltage Engineering”, Newnes, 2000.
4. Kuffel and Abdulla. M. “High Voltage Engineering”, Pergamon press, 1998.
5. Wadhwa C L., “High Voltage Engineering”, Wiley Eastern Limited, NewDelhi, 1994.

## EE 6503: Power System Transients

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

**Module 1 (12 hours)**
Fundamental circuit analysis of electrical transients -The Laplace Transform method of solving-simple Switching transients -Damping circuits -Abnormal switching transients Three-phase circuits and transients. Computation of power system transients -Principle of digital computation – Matrix method of solution- Modal analysis- Z transform- Computation using EMTP.

**Module 2 (10 hours)**
Lightning, switching and temporary overvoltages Lightning: Physical phenomena of lightning – Interaction between lightning and power system – Influence of tower footing resistance and earth Resistance- Switching: Short line or kilometric fault – Energizing transients - closing and re-closing of lines - line dropping, load rejection – over voltages induced by fault – Switching HVDC lines.

**Module 3 (10 hours)**
Travelling waves on transmission line : Circuits with distributed Parameters – Wave Equation – Reflection, Refraction, Behaviour of Travelling waves at the line terminations – Lattice Diagrams – Attenuation and Distortion – Multi-conductor system and Velocity wave.

**Module 4 (10 hours)**
Insulation co-ordination: Principle of insulation co-ordination in Air Insulated substation (AIS) and Gas Insulated Substation (GIS)- co-ordination between insulation and protection level – statistical approach- Protective devices- Protection of system against overvoltages– lightning arresters, substation earthing.

Text Book

1. Allan Greenwood, “Electrical Transients in Power System”, Wiley & Sons Inc. New York, 1991.

## EE6301: Power Electronic Circuits

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

**Module 1: (11 hours)**
D.C.chopper circuits, Type-A, B, C, D and E configurations, Analysis of Type-A chopper with R-L load. -Voltage and current commutated Choppers
Line Frequency Diode Rectifiers . Single-Phase Diode Bridge Rectifiers with Capacitor Filter . Voltage Doubler Rectifiers . Effect of Single Phase Rectifiers on Neutral Currents in a Three Phase Four-Wire System.
Three Phase half wave rectifier with resistive load . Three phase full wave rectifier . Double Y type rectifier . Single Phase rectifiers with LC filter . LC Filter Design. Three Phase Rectifier Circuits. Input Line Current Harmonics and power factor.

**Module 2: (10 hours)**
Line Frequency Phase-Controlled Rectifiers and Inverters .Single Phase - Half Wave Controlled Rectifier with R , RL , RL with Flywheel diode loads . Full Wave Controlled Rectifier with various kinds of loads . Half Controlled and Full Controlled Bridges with passive and active loads - Input Line Current Harmonics and Power Factor- Inverter Mode of Operation - Three Phase . Half Wave Controlled rectifier with RL Load . Half Controlled Bridge with RL Load . Fully Controlled Bridge with RL Load . Input Side Current Harmonics and Power Factor - Dual Converters . Circulating Current Mode and Non-Circulating Current Mode .

**Module 3: (10 hours)**
Switch-Mode dc-ac Inverters. Basic Concepts. Single Phase Inverters. PWM Principles. Sinusoidal Pulse Width Modulation in Single Phase Inverters . Choice of carrier frequency in SPWM. Spectral Content of output. Bipolar and Unipolar Switching in SPWM - Blanking Time Maximum Attainable DC Voltage Switch Utilization .Reverse Recovery Problem and Carrier Frequency Selection . Output Side Filter Requirements and Filter Design - Ripple in the Inverter Output - DC Side Current. - Three Phase Inverters -Three Phase Square Wave /Stepped Wave Inverters . Three Phase SPWM Inverters. Choice of Carrier Frequency in Three Phase SPWM Inverters. Output Filters. DC Side Current. Effect of Blanking Time on Inverter Output Voltage.

**Module 4: (11 hours)**
Converters for Static Compensation. Standard Modulation Strategies - Programmed Harmonic Elimination . Multi-Pulse Converters and Interface Magnetics. Multi-Level Inverters of Diode Clamped Type and Flying Capacitor Type and suitable modulation strategies -Space Vector Modulation - Minimum ripple current PWM method. Multi-level inverters of Cascade Type. Current Regulated Inverter -Current Regulated PWM Voltage Source Inverters . Methods of Current Control. Hysteresis Control. Variable Band Hysteresis Control . Fixed Switching Frequency Current Control Methods. Switching Frequency Vs accuracy of Current Regulation Areas of application of Current Regulated VSI.

**References**

1. Ned Mohan et.al “Power electronics : converters, applications, and design” John Wiley and Sons, 2006.
2. P.C. Sen “Power Electronics” Tata McGraw Hill, 2003.
3. G.K.Dubey et.al “Thyristorised Power Controllers” Wiley Eastern Ltd., 2005.
4. Dewan & Straughen “Power Semiconductor Circuits” John Wiley & Sons, 1975.
5. M.D.Singh & K.B.Khanchandani “Power Electronics” Tata McGraw Hill., 2007.
6. B. K Bose Modern Power Electronics and AC Drives. Pearson Education (Asia), 2007.

**EE6591 High Voltage Lab**

1. Measurement of HVAC Voltage using Chubb and Fortescue method
2. Measurement of AC voltage using sphere gap
3. Measurement of HVAC using voltage dividers
4. Study of Impulse generators and generation of standard lightning waveform
5. DC breakdown studies on solid insulators
6. Estimation of AC breakdown strength of paper insulation
7. Estimation of AC breakdown strength of oil
8. Filed plotting using ANSYS and COMSOL
9. Preparation and testing of nanocomposite insulator

## EE 6502: Computational Electromagnetics

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**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

**Module 1: (11 hours)**
Review of basic field theory – electric and magnetic fields – Maxwell's equations –Laplace, Poisson and Helmoltz equations – principle of energy conversion – force/torque calculation – Electro thermal formulation.

**Module 2: (11 hours)**
Limitations of the conventional design procedure need for the field analysis based design, problem definition and solution by analytical methods-direct integration method – variable separable method – method of images, solution by numerical methods- Finite Difference Method.

**Module 3: (9 hours)**
Finite element method (FEM) – Differential/ integral functions – Variational method –Energy minimization – Discretisation – Shape functions –Stiffness matrix –1D and 2D planar and axial symmetry problem.

**Module 4: (11 hours)**
Design Applications: Insulators- Bushings – Cylindrical magnetic actuators – Transformers – Rotating machines.

**References**


1. Karl E. Lonngren, Sava V. Savov, Randy J. Jost, "Fundamentals of Electromagnetics with MATLAB", 2nd edition, SciTech Publishing, Inc., 2007.
2. George W. Pan, "Wavelets in Electromagnetics and Device Modeling", Wiley.
3. Jaan Kiusalaas, " Numerical Methods in Engineering with Python", Cambridge University Press.
4. Chen, Cao and Mittra , "Multiresolution Time Domain Scheme for Electromagnetic Engineering".
5. A Daniel G. Swanson, Wolfgang J. R. Hoefer , "Microwave circuit modeling using electromagnetic field simulation".
6. Sergey N. Makarov , "Antenna and EM Modeling with Matlab".

**EE6504: Physics of Dielectrics**

| L | T | P | C |
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**Pre-requisite: EE6501 High Voltage Engineering**
**Total hours: 42 Hrs.**

**Module 1: (11 hours)**
Introduction to dielectrics and electrical insulation systems used in high voltage power apparatus: gaseous, vacuum, liquid, solid and composite insulation, behaviour of dielectrics in electric and thermal fields, polarization, relaxation, permittivity and dielectric loss, space charge in dielectrics.

**Module 2: (11 hours)**
Dielectric Formalism, Equivalent circuits, intrinsic dielectric strength, mechanisms of electrical and thermal breakdown in solids, Phenomenological theory of ageing, mechanisms of ageing under electrical, thermal and combined stresses, Accelerated ageing tests. Statistical models for Insulation failure, Ageing data analysis, Ageing and failure due to partial discharges.

**Module 3: (10 hours)**
Polymers as dielectrics in various electrical equipments, polymer structure and morphology, classification of polymers, filled polymers for HV applications, introduction to electrical degradation in nanodielectrics– treeing, partial discharge, tracking & erosion.

**Module 4: (10 hours)**
Design of insulation systems used in various power apparatus (case studies) - transformers, bushings, circuit breakers, cables, capacitors, high voltage rotating machines, gas insulated substations and transmission lines, Computational dielectrics.

**References**

1. T S Ramu and Chakradhar Reddy, “Reliability and Life estimation of Power Equipment”, New Age International 2009.
2. M. S. Naidu, V. Kamaraju, "High Voltage Engineering", McGraw-Hill, 1995.
3. Kuffel and Zaengal .High Voltage Engineering, Newnes,2000
4. Kuffel and Abdulla.M. .High Voltage Engineering, Pergamon press, 1998
5. Wadhwa C L., .High Voltage Engineering.., Wiley Eastern Limited, NewDelhi,1994
6. Relevant IS standards and IEC standards
7. Bottcher C.J.F., Theory of Electric Polarisation, Elsevier Publication, 1962,
8. Mann N.R. Scholar R.E. and Singaporewalla N.D., Methods of Statistical Analysis and Life Data, John Wiley and Sons, New York, 1974.
9. Current literature from journals and conference proceedings.

## EE6506: EHV Power Transmission

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**Pre-requisite-Nil**

**Module 1 (10 hours)**

Overview of Electrical power transmission at high voltages. Overhead transmission lines : Bundled conductors, Resistance, Inductance and capacitance calculations of EHV line and multiconductor configurations-seuqence inductance and capacitance-line parameters for modes of propagation-Temperature rise of conductors and current carrying capacity.

**Module 2 (12 hours)**

Computation of surface voltage gradient on conductors Corona: Power loss due to corona, Radio noise and Audible noise and their measurement as well as computation. Electric Field under transmission lines and its computation Effect of ES fields of humans, Animals and plants.

**Module 3 (10 hours)**

Theory of reactive power control-Series and Shunt Compensation: Effect of series capacitors, Location of series capacitors. Sub-synchronous resonance in series-capacitor compensated lines and counter measures, Shunt compensation- Static VAR systems: TCR, TCR-FC, TSC-TCR and MSC-TCR schemes

**Module 4 (10 hours)**

HVDC Transmission: HVDC transmission, kind of dc links, light activated thyristor, series and parallel connection of thyristors. Scheme of converter station, 12 – pulse converter -HVDC Link: Control of HVDC link, Converter control characteristics, firing angle control and extinction angle control. Comparison between AC and DC transmissions Applications of HVDC transmission. Power modulation and power control of HVDC lines.

**References**


1. R.D. Begamudre , “EHV AC transmission engineering”, New age international, 2006.
2. Kimbark E.W., “HVDC transmission”, Wiley, 1965.
3. Arrilaga J, “High voltage Direct Current Transmission”, Peter pregrinus, London, 2007.

## EE6201: Computer Methods in Power Systems

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

**Module 1: (11 hours)**
System Graph. Loop, Cutest And Incidence Matrices. Y Bus Formation. Power Flow Analysis: Newton-Raphson Method. Decoupled And Fast Decoupled Methods, DC Power Flow, Sparsity And Optimal Ordering, AC-DC Load Flow Analysis.

**Module 2: (10 hours)**
Fault Analysis : [$Z_{BUS}$] Building Algorithm . Sequence Matrices. Symmetrical And Unsymmetrical Short-Circuit Analysis of Large Power Systems. Phase Shift In Sequence Quantities Due To Transformers.

**Module 3: (11 hours)**
Power System Optimization. Unit Commitment. Priority List And Dynamic Programming Methods. Optimal Load Flow Solution. Optimal Scheduling of Hydrothermal System. Introduction to Optimum Reactive Power Dispatch, AI Applications.

**Module 4: (10 hours)**
Power System. Security. Factors Affecting Security. State Transition Diagram. Contingency Analysis Using Network Sensitivity Method And AC Power Flow Method, Correcting The Generation Dispatch Using Sensitivity Methods, State Estimation.

**References**

1. Hadi A. Sadat, "Power System Analysis", McGraw Hill Co. Ltd., India, 2000.
2. I.J. Nagarath, D.P. Kothari, "Power System Engineering", Tata McGraw Hill Publishing Co. Ltd., New Delhi, 1994.
3. George L. Kusic, "Computer Aided Power System Analysis", Prentice Hall of India (P) Ltd., New Delhi, 1989.
4. A.J. Wood, B.F. Wollenberg, .Power Generation, Operation and Control., John Wiley & Sons, New York, 1984.
5. J. Arrilaga, C.P. Arnold, B.J. Harker, "Computer Modelling of Electric Power Systems", Wiley, New York, 1983.
6. A.K. Mahaianabis, D.P. Kothari, S.I. Ahson, "Computer Aided Power System Analysis & Control", Tata McGraw Hill, New Delhi, 1988.
7. B.R. Gupta, "Power System Analysis and Design", (3rd Edition), A.H. Wheeler & Co. Ltd., New Delhi, 1998.
8. O.I. Elgard, .Electric Energy System Theory: An Introduction., 2nd Edition, McGraw Hill, New York, 1982.

## EE6222: Power Quality

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Module 1: (9 hours)**
Introduction-power quality-voltage quality-overview of power quality phenomena-classification of power quality issues-power quality measures and standards-THD-TIF-DIN-C-message weights-flicker factor-transient phenomena-occurrence of power quality problems-power acceptability curves-IEEE guides, standards and recommended practices.

**Module 2: (10 hours)**
Harmonics-individual and total harmonic distortion-RMS value of a harmonic waveform-triplex harmonics-important harmonic introducing devices-SMPS-Three phase power converters-arcing devices-saturable devices-harmonic distortion of fluorescent lamps-effect of power system harmonics on power system equipment and loads.
Modeling of networks and components under non-sinusoidal conditions-transmission and distribution systems-shunt capacitors-transformers-electric machines-ground systems-loads that cause power quality problems-power quality problems created by drives and its impact on drives.

**Module 3: (12 hours)**
Power factor improvement- Passive Compensation . Passive Filtering . Harmonic Resonance . Impedance Scan Analysis- Active Power Factor Corrected Single Phase Front End, Control Methods for Single Phase APFC, Three Phase APFC and Control Techniques, PFC Based on Bilateral Single Phase and Three Phase Converter. static var compensators-SVC and STATCOM.

**Module 4: (11 hours)**
Active Harmonic Filtering-Shunt Injection Filter for single phase, three-phase three-wire and three-phase four-wire systems. d-q domain control of three phase shunt active filters uninterruptible power supplies-constant voltage transformers- series active power filtering techniques for harmonic cancellation and isolation . Dynamic Voltage Restorers for sag , swell and flicker problems.
Grounding and wiring-introduction-NEC grounding requirements-reasons for grounding-typical grounding and wiring problems-solutions to grounding and wiring problems.

**References**
1. G.T. Heydt, Electric power quality, McGraw-Hill Professional, 2007
2. Math H. Bollen, Understanding Power Quality Problems, IEEE Press, 2000
3. J. Arrillaga, .Power System Quality Assessment., John wiley, 2000

## EE6308: FACTS and Custom Power

| L | T | P | C |
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| 3 | 0 | 0 | 3 |

**Total hours: 42 Hrs**

**Module 1: (10 hours)**
Power flow in Power Systems – Steady-state and dynamic problems in AC systems – Voltage regulation and reactive power flow control in Power Systems – control of dynamic power unbalances in Power System - Power flow control -Constraints of maximum transmission line loading - Benefits of FACTS Transmission line compensation- Uncompensated line -shunt compensation - Series compensation -Phase angle control.
Reactive power compensation – shunt and series compensation principles – reactive compensation at transmission and distribution level – Static versus passive VAr Compensators .

**Module 2: (11 hours)**
Static shunt compensators: SVC and STATCOM - Operation and control of TSC, TCR and STATCOM - Compensator control - Comparison between SVC and STATCOM.
Static series compensation: TSSC, SSSC -Static voltage and phase angle regulators - TCVR and TCPAR- Operation and Control -Applications. Static series compensation – GCSC,TSSC, TCSC and Static synchronous series compensators and their control, SSR and its damping .

**Module 3: (10 hours)**
Unified Power Flow Controller: Circuit Arrangement, Operation and control of UPFC- Basic Principle of P and Q control- independent real and reactive power flow control- Applications - Introduction to interline power flow controller.
Modelling and analysis of FACTS Controllers – simulation of FACTS controllers

**Module 4: (11hours)**
Power quality problems in distribution systems, harmonics, loads that create harmonics, modeling, harmonic propagation, series and parallel resonances, mitigation of harmonics, passive filters, active filtering – shunt , series and hybrid and their control – voltage swells , sags, flicker, unbalance and mitigation of these problems by power line conditioners- IEEE standards on power quality.

**References**

1. K R Padiyar, "FACTS Controllers in Power Transmission and Distribution", New Age International Publishers, 2007
2. X P Zhang, C Rehtanz, B Pal, "Flexible AC Transmission Systems- Modelling and Control", Springer Verlag, Berlin, 2006
3. N.G. Hingorani, L. Gyugyi, "Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems", IEEE Press Book, Standard Publishers and Distributors, Delhi, 2001.
4. K.S.Sureshkumar , S.Ashok , "FACTS Controllers & Applications", E-book edition, Nalanda Digital Library, NIT Calicut,2003
5. G T Heydt , Power Quality, McGraw-Hill Professional, 2007
6. T J E Miller, Static Reactive Power Compensation, John Wiley and Sons, New York, 1982

## EE 6505: High Voltage DC Transmission

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

**Module 1: (11 hours)**
Introduction – Comparison of AC and DC transmission – Application of DC transmission – Description of DC transmission system – Planning for HVDC transmission – Modern trends in DC transmission – DC breakers – Cables – VSC based HVDC.

**Module 2: (11 hours)**
Pulse number – Choice of converter configuration – Simplified analysis of Graetz circuit - Converter bridge characteristics – Detailed analysis of converters - General principles of DC link control – Converter control – System control hierarchy - Firing angle control – Current and extinction angle control – Generation of harmonics and filtering, Filter design.

**Module 3: (9 hours)**
Introduction – Potential applications of MTDC systems – Types of MTDC systems – Control and protection of MTDC systems – Study of MTDC systems.

**Module 4: (11 hours)**
Introduction – System simulation: Philosophy and tools – HVDC system simulation –Modeling of HVDC systems for digital dynamic simulation – Dynamic interaction between DC and AC systems. Power flow analysis of AC-DC systems. Transient stability analysis.

**References**


1. Kimabrk E.W., HVDC Transmission, 1st Ed., Wiley,1965.
2. Arrillaga J., “High Voltage Direct Current Transmission”, Peter Pregrinus, London, 2007.
3. Kundur P., “Power System Stability and Control”, Tata McGraw-Hill, 1993.
4. Erich Uhlmann, “Power Transmission by Direct Current”, BS Publications, 2004.
5. Sood V.K., “HVDC and FACTS controllers – Applications of Static Converters in Power System”, Kluwer Academic Publishers, April 2004.

## EE6426: Distribution Systems Management and Automation

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Prerequisite: Nil**
**Total hours: 42 Hrs**

**Module 1: (10 Hours)**
Distribution Automation System : Necessity, System Control Hierarchy- Basic Architecture and implementation Strategies for DA- Basic Distribution Management System Functions- Outage management-
Integration of Distributed Generation and Custom Power components in distribution systems- Distribution system Performance and reliability calculations

**Module 2: (10 Hours)**
Electrical System Design: Distribution System Design- Electrical Design Aspects of Industrial, Commercials Buildings- Electrical Safety and Earthing Practices at various voltage levels- IS Codes

**Module 3: (12 Hours)**
Communication Systems for Control and Automation- Wireless and wired Communications- DA Communication Protocols, Architectures and user interface-Case Studies

**Module 4: (10 Hours)**
Power Quality and Custom Power: Concept- Custom Power Devices - Operation and Applications
Deregulated Systems: Reconfiguring Power systems- Unbundling of Electric Utilities- Competition and Direct access

**References**

1. James Northcote – Green, Robert Wilson, “Control and Automation of Electrical Power Distribution Systems”, CRC Press, New York, 2007.
2. Turan Gonen: .Electric Power Distribution System Engineering. McGraw Hill Company. 1986
3. M.V Deshpande: .Electrical Power System Design. Tata-McGraw Hill, 1966
4. IEEE Press: IEEE Recommended practice for Electric Power Distribution for Industrial Plants, published by IEEE, Inc., 1993
5. Pansini, Electrical Distribution Engineering, The Fairmont Press, Inc., 2007
6. Pabla H S.: .Electrical Power Distribution Systems.. Tata McGraw Hill. 2004
7. IEEE Standerd 739 . Recommended Practice for Energy Conservation and Cost Effective Planning in Industrial Facilities. 1984
8. G H Heydt .Electric Power Quality. McGram Hill, 2007
9. Wilson K. Kazibwe and Musoke H Semdaula .Electric Power Quality Control Techniques.. Van Nostarand Reinhold New York, 2006
10. Lakervi & E J Holmes .Electricity distribution network design., 2nd Edition Peter Peregrimus Ltd. 1995

**EE6122: Biomedical Instrumentation**

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

**Module 1: (12 hours)**
Fundamentals of medical instrumentation – physiological systems of body –regulation of medical devices – origin of bio potentials – Sodium –Potassium pump –Goldman Hodgkin – Katz equation – biomedical transducers – electrode-electrolyte interface – half cell potential – ECG – 12 lead systems – heart rate variability – cardiac pacemakers – defibrillators - EMG – EEG

**Module 2: (10 hours)**
Measurement of cardiac output – indicator dilution method – ultrasonic blood flow meter – electromagnetic blood flow meter – blood pressure measurement – oximetry – ear oximeter – pulse oximeter –skin reflectance oximeter -measurement on pulmonary system – spirometry –pulmonary function analyzers –ventilators
.

**Module 3: (10 hours)**
Lasers in medicine – Argon laser – Carbon dioxide laser -laser safety –X ray applications –X-ray machine – dental X-ray machine – ultra sound in medicine –electro therapy – hemodialysis – artificial kidney – dialyzers –membranes for hemodialysis

**Module 4: (10 hours)**Measurement of $P_{H}$, $PCO_2$, $PO_2$ - radiotherapy – Cobalt 60 machine – medical linear accelerator machine – audiometry - electrical safety in hospitals.

**References**


1. Geddes & Baker, Principles of Applied Biomedical Instrumentation Wiley Inter science , 3rd edition, 1975
2. R S Khandpur, Hand book of Biomedical instrumentation, TMH,4th edition, 1987
3. Cromwell Leslie, Biomedical instrumentation and measurements, PHI, 1980
4. Brown Carr, Introduction to Biomedical Equipment Technology, Printice Hall, 1981
5. John Enderle, Introduction to Biomedical Engineering, Academic Press, 2005
6. Joseph D Bronzino, Biomedical engineering hand book, CRC Press, 2000
7. Metin Akay (editor), Wiley encyclopedia of Biomedical Engineering, Wiley, 2003

## EE6103: Applied Instrumentation

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

**Module 1: (10 hours)**
Introductory Instrumentation to process control. Modeling philosophies. The rationals for mathematical modeling dynamic versus steady state models. General modeling principles degrees of freedom in modeling. Control systems instrumentation . Transducers and transmitters. Transfer function models. Procedure for developing transfer function models.

**Module 2: (10 hours)**
Performance modeling. Modeling automated manufacturing system (introduction). Role of performance modeling. Performance measures. Petrinet models . Introduction to petrinets. Basic definitions and analytical techniques. S-net models. Preliminary definition and analytical techniques.

**Module 3: (10 hours)**
Roll for digital computer system in process control. Distributed instrumentation and control system . General purpose digital data acquisition and control hardware.

**Module 4: (12 hours)**
Engineered Data Acquisition and Processing System. Versatile Modular System Emphasising Analog Signal Processing. Instrument Inter Connection Systems. Sensor based computerized data system. Computer Aided Experimentation. Conditional description of the computer system. Computer aided overall plan of the test sequence.

**References**

1. Seborg. Process dynamic control, Wiley, 2007
2. Ernest O. Doebelin. Measurement system Application and Design. McGraw Hill International Editions, 1990
3. N. Viswanathan, Y. Narahari. Performance modeling of automated manufacturing system, Prentice Hall of India Private Limited, New Delhi, 2001
4. Proceedings: Conference on Advances in computing, CADCOM 98, Allied Publishers Limited, New Delhi, India, 1999

## EE6428: SCADA Systems and Applications

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite-Nil**
**Total hours: 42 Hrs**

**Module 1: (10 hours)**
Introduction to SCADA**:** Data acquisition systems, Evolution of SCADA, Communication technologies, Monitoring and supervisory functions, SCADA applications in Utility Automation, Industries

**Module 2: (11 hours)**
SCADA System Components**:** Schemes- Remote Terminal Unit (RTU),Intelligent Electronic Devices (IED),Programmable Logic Controller (PLC), Communication Network, SCADA Server, SCADA/HMI Systems

**Module 3: (11 hours)**
SCADA Architecture**: V**arious SCADA architectures, advantages and disadvantages of each system **-** single unified standard architecture **-**IEC 61850. SCADA Communication**:** various industrial communication technologies -wired and wireless methods and fiber optics. open standard communication protocols.

**Module 4: (10 hours)**
SCADA Applications**:** Utility applications- Transmission and Distribution sector **-**operations, monitoring, analysis and improvement. Industries **-** oil, gas and water. Case studies, Implementation, Simulation Exercises

**References**
1. Stuart A. Boyer: SCADA-Supervisory Control and Data Acquisition, Instrument Society of America Publications, USA, 2004.
2. Gordon Clarke, Deon Reynders: Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems, Newnes Publications, Oxford, UK, 2004.
3. William T. Shaw, Cybersecurity for SCADA systems, PennWell Books, 2006.
4. David Bailey, Edwin Wright, Practical SCADA for industry, Newnes, 2003.
5. Michael Wiebe, A guide to utility automation: AMR, SCADA, and IT systems for electric power, PennWell 1999.

## EE6129: Artificial Neural Networks and Fuzzy Systems

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs**

**Module 1: (10 hours)**
Biological foundations, ANN models, Types of activation function, Introduction to Network architectures : Multi Layer Feed Forward Network (MLFFN), Radial Basis Function Network (RBFN), Recurring Neural Network (RNN)

**Module2:(10hours)**
Learning process. Supervised and unsupervised learning . Error-correction learning, Hebbian learning, Boltzmen learning, Single layer and multilayer perceptурs, Least mean square algorithm, Back propagation algorithm, Applications in forecasting and pattern recognition and other engineering problems.

**Module3:(10hours)**
Fuzzy sets . Fuzzy set operations . Properties, Membership functions, Fuzzy to crisp conversion. fuzzification and defuzzification methods, applications in engineering problems.

**Module4:(12hours)**
Fuzzy control systems . Introduction, simple fuzzy logic controllers with examples, special forms of fuzzy logic models, classical fuzzy control problems . inverter pendulum, image processing . home heating system . Adaptive fuzzy systems,hybrid systems.

**References**

1. J.M. Zurada, .Introduction to artificial neural systems., Jaico Publishers, 1992.
2. Simon Haykins, .Neural Networks . A comprehensive foundation., Macmillan College, Proc, Con, Inc, New York, 1994.
3. D. Driankov, H. Hellendorn, M. Reinfrank, .Fuzzy Control . An Introduction. , Narora Publishing House, New Delhi, 1993.
4. H.J. Zimmermann, .Fuzzy set theory and its applications., III Edition, Kluwer Academic Publishers, London. 2001
5. G.J. Klir, Boyuan, .Fuzzy sets and fuzzy logic., Prentice Hall of India (P) Ltd., 1997.
6. Stamatios V Kartalopoulos, .Understanding neural networks and fuzzy logic .basic concepts and applications., Prentice Hall of India (P) Ltd., New Delhi, 2000.
7. Timothy J. Ross, .Fuzzy logic with engineering applications., McGraw Hill, New York.
8. Suran Goonatilake, Sukhdev Khebbal (Eds), .Intelligent hybrid systems., John Wiley & Sons, New York, 1995.

## EE6304: Advanced Digital Signal Processing

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs**

**Module1: Discrete Time Signals, Systems and Their Representations (12 hours)**
Discrete time signals- Linear shift invariant systems- Stability and causality- Sampling of continuous time signals- Discrete time Fourier transform- Discrete Fourier series- Discrete Fourier transform- Z-transform- Properties of different transforms- Linear convolution using DFT- Computation of DFT

**Module 2: Digital Filter Design and Realization Structures (9 hours)**
Design of IIR digital filters from analog filters- Impulse invariance method and Bilinear transformation method- FIR filter design using window functions- Comparison of IIR and FIR digital filters- Basic IIR and FIR filter realization structures- Signal flow graph representations

**Module 3: Analysis of Finite Word-length Effects (9 hours)**
Quantization process and errors- Coefficient quantisation effects in IIR and FIR filters- A/D conversion noise- Arithmetic round-off errors- Dynamic range scaling- Overflow oscillations and zero input limit cycles in IIR filters

**Module 4: Statistical Signal Processing (12 hours)**
Linear Signal Models . All pole, All zero and Pole-zero models .Power spectrum estimation- Spectral analysis of deterministic signals . Estimation of power spectrum of stationary random signals-Optimum linear filters-Optimum signal estimation-Mean square error estimation-Optimum FIR and IIR filters.

**References**

1. Sanjit K Mitra, Digital Signal Processing: A computer-based approach ,Tata Mc Grow-Hill edition .1998
2. Dimitris G .Manolakis, Vinay K. Ingle and Stephen M. Kogon, Statistical and Adaptive Signal Processing, Mc Grow Hill international editions .-2000
3. Alan V . Oppenheim, Ronald W. Schafer, Discrete-Time Signal Processing, Prentice-Hall of India Pvt. Ltd., New Delhi, 1997
4. John G. Proakis, and Dimitris G. Manolakis, Digital Signal Processing(third edition), Prentice-Hall of India Pvt. Ltd, New Delhi, 1997
5. Emmanuel C. Ifeachor, Barrie W. Jervis , Digital Signal Processing-A practical Approach, Addison . Wesley,1993
6. Abraham Peled and Bede Liu, Digital Signal Processing, John Wiley and Sons, 1976

## EE6323: Digital Simulation of Power Electronic Systems

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs**

**Module 1: (10 hours)**
Principles of Modeling Power Semiconductor Devices - Macromodels versus Micromodels - Thyristor model - Semiconductor Device modelled as Resistance, Resistance-Inductance and Inductance-Resistance-Capacitance combination - Modelling of Electrical Machines - Modelling of Control Circuits for Power Electronic Switches. Computer Formulation of Equations for Power Electronic Systems - Review of Graph Theory as applied to Electrical Networks - Systematic method of Formulating State Equations - Computer Solution of State Equations - Explicit Integration method - Implicit Integration method.

**Module 2: (10 hours)**
Circuit Analysis Software MicroSim PSpice A/D - Simulation Overview - Creating and Preparing a Circuit for Simulation - Simulating a Circuit with PSpice A/D - Displaying Simulation Results - PSpice A/D Analyses - Simple Multi-run Analyses - Statistical Analyses - Simulation Examples of Power Electronic systems.

**Module 3: (10 hours)**
MicroSim PSpice A/D - Preparing a Schematic for Simulation - Creating Symbols - Creating - Models - Analog Behavioral Modeling - Setting Up and Running analyses - Viewing Results - Examples of Power Electronic Systems. MATLAB SIMULINK in Power system.

**Module 4: (12 hours)**
Design Creation and Simulation with SaberDesigner - Placing the Parts - Editing the Symbol - Properties - Wiring the Schematic - Modifying Wire Attributes - Performing a Transient and DC Analysis - Placing Probes in the Design - Performing AC Analysis and Invoking SaberScope - Analysing waveforms with SaberScope - Performing Measurements on a waveform - Varying a Parameter - Displaying the Parameter Sweep Results - Measuring a Multi-Member Waveform - Simulation Examples of Power Electronic Systems.

**References**

1. V.Rajagopalan: Computer Aided Analysis of Power Electronic Systems - Marcel Dekker, Inc,1987.
2. MicroSim PSpice A/D and Basics+: Circuit Analysis Software, User's Guide, MicroSim Corporation.
3. MicroSim Schematics: Schematic Capture Software, User's Guide, MicroSim Corporation.
4. Getting Started with SaberDesigner (Release 5.1) , An Analogy Inc.
5. Guide to Writing MAST Template (Release 5-1), Analogy Inc.

## EE6422: Engineering Optimization

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite-Nil**
**Total hours: 42 Hrs**

**Module 1: (11 hours)**
Concepts of optimization: Engineering applications-Statement of optimization problem-Classification - type and size of the problem.
Classical Optimization Techniques: Single and multi variable problems-Types of Constraints .Semi definite case-saddle point.
Linear programming: Standard form-Geometry of LP problems-Theorem of LP-Relation to convexity - formulation of LP problems - simplex method and algorithm -Matrix form- two phase method.
Duality- dual simplex method- LU Decomposition. Sensitivity analysis .Artificial variables and complementary solutions-QP.
Engineering Applications: Minimum cost flow problem, Network problems-transportation, assignment & allocation, scheduling . Karmarkar method-unbalanced and routing problems.
**Module 2: (11 hours)**
Nonlinear programming: Non linearity concepts-convex and concave functions- non-linear programming - gradient and Hessian.
Unconstrained optimization: First & Second order necessary conditions-Minimisation & Maximisation-Local & Global convergence-Speed of convergence.
Basic decent methods: Fibonacci & Golden section search - Gradient methods - Newton Method-Lagrange multiplier method - Kuhn-tucker conditions . Quasi-Newton method- separable convex programming - Frank and Wolfe method, Engineering Applications.
**Module 3: (10 hours)**
Nonlinear programming- Constrained optimization: Characteristics of constraints-Direct methods-SLP,SQP-Indirect methods-Transformation techniques-penalty function-Langrange multiplier methods-checking convergence- Engineering applications
**Module 4: (10 hours)**
Dynamic programming: Multistage decision process- Concept of sub optimization and principle of optimality- Computational procedure- Engineering applications.
Genetic algorithms- Simulated Annealing Methods-Optimization programming, tools and Software packages.

**References**

1. David G Luenberger, .Linear and Non Linear Programming., 2nd Ed, Addison-Wesley Pub.Co.,Massachusetts, 2003
2. W.L.Winston, .Operation Research-Applications & Algorithms.,2nd Ed., PWS-KENT Pub.Co.,Boston, 2007
3. S.S.Rao, .Engineering Optimization., 3rd Ed.,New Age International (P) Ltd,New Delhi, 2007
4. W.F.Stocker, .Design of Thermal Systems., 3rd Ed., McGraw Hill, New York. 1990
5. G.B.Dantzig, .Linear Programming and Extensions. Princeton University Press, N.J., 1963.
6. L.C.W.Dixton,. Non Linear Optimisation: theory and algorithms. Birkhauser, Boston, 1980
7. Bazarra M.S., Sherali H.D. & Shetty C.M., .Nonlinear Programming Theory and Algorithms., John Wiley,New York,1979.
8 A. Ravindran, K. M. Ragsdell, G. V. Reklaitis, Engineering Optimization: Methods And Applications, Wiley, 2008
9 Godfrey C. Onwubolu, B. V. Babu, New optimization techniques in engineering, Springer, 2004
10. Kalyanmoy Deb,.Optimisation for Engineering Design-Algorithms and Examples., Prentice Hall India-1998

## NS6101 Structure of Nanomaterials

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**

**Module I (12 Hours)**
Classification of nanostructures, nanoscale architecture, fundamental structure, chemistry, property relationships in nanomaterials and nanomaterial systems. Top-down processes, bottom-up processes, methods for templating the growth of Nanomaterials Ordering of nanosystems, preparation, safety and storage issues

**Module II (10 Hours)**
Electronic properties of atoms and solids, the isolated atom, bonding between atoms, giant molecular solids, the free electron model and energy bands, band theory, crystallography, fundamentals of mechanical, electrical and magnetic properties of nanomaterials.

**Module III (10 Hours)**
Nanocrystalline materials, nanocomposities, quantum well structures, extreme ultraviolet (EUV) optical elements and grain size determination in nanomaterials and nanometer scale systems.

**Module IV (10 Hours)**
Nanoscale x-ray -electron and neutron diffraction techniques, Application areas, Scanning electron microscopy, Transmission electron microscopy , Atomic force microscopy (AFM), Scanning tunneling microscopy (STM).

**References**

1. Callister, William D. Jr., Fundamentals of Materials Science and Engineering: An Integrated Approach 2nd Ed., John Wiley and Sons, 2003
2. S. N. Sahu, R. K. Choudhury, and P. Jena, Nano-scale Materials: From Science to Technology, Nova Science Publishers, 2006.
3. Yannick Champion , Hans-Jörg Fecht, Nano-Architectured and Nanostructured Materials: Fabrication, Control and Properties, Wiley-VCH,2005.
4. Robert K, Ian H, Mark G, Nanoscale Science and Technology, John Wiley & sons Ltd.,2005

## NS6112 Experimental Techniques in Nanotechnology

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**

**Module 1 (10 hours)**
Statistical principles for design-of-experiment methods as applied to nanomaterials selfassembly, processing, and associated development of analytical protocols. Elementary ideas of blocking, general principles of linear model analysis. Introduction to replication, covariance, experimental treatment structures, and full- and partial-factorial designs.

**Module 2 (8 hours)**
Experimental techniques for temperature measurement – thermoreflectance thermometry – measurement of thermal phenomena in nanofluids – thermal conductivity measurement in nanofluids using steady state and transient methods.

**Module 3 (12 Hours)**
Characterization techniques in nanotechnology - Micorscopy - instrumentation and application, Sample preparation - contrast mechanisms - Scanning probe microscopy, tapping mode, contact mode, phase image, Scanning electron microscopy, Transmission electron microscopy and HRTEM, Scanning tunneling microscopy, Optical microscopy, Scanning near field microscopy - Electron back scattering - X-ray micro analysis.

**Module 4 (12 Hours)**
Spectroscopic Methods - Fundamental principles and experimental implementation of xray/electron diffraction, Raman spectroscopy - Auger Electron Spectroscopy, X-Ray Photoelectron Spectroscopy, Secondary Ion Mass Spectrometry, Energy-dispersive X-ray Spectroscopy.

**References**
1. Robert K, Ian H, Mark G, Nanoscale Science and Technology, john Wiley & sons Ltd.,2005
2. Weilie Zhou and Zhong Lin Wang, Scanning Microscopy for Nanotechnology, Springer 2006.
3. Nan Yaho and Zhong, Hand book of Microscopy for Nanotechnology, Kluwer Academic press, Boston, 2005.
4. K.S Birdi, Scanning Probe Microscopy, CRC Press, 2003.
5. C B Sobhan, G P Peterson, Microscale and Nanoscale Heat Transfer-Fundamentals and Engineering Applications, Taylor and Francis/CRC, 2008.
6. Ernest O Doeblin., "Measurement Systems: Application and Design", McGraw Hill (Int. Edition) 1990.

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# NS6124 Computational Nanotechnology

**Pre-requisite: Nil**

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Module 1 (11 hours)**

## Introduction:

Computational simulation, need for discrete computation.

## Classical Mechanics:

Mechanics of Particles, D'Alembert's principle and Lagrange's equation, variational principles, Hamilton's principle, conservation theorems and symmetry properties, central force problems, virial theorem.

**Module 2 (11 hours)**

## Statistical Mechanics:

Review of probability and statistics, quantum states of a system, equations of state, canonical and microcanonical ensemble, partition function, energy levels for molecules, equipartition theorem, minimizing the free energy, partition function for identical particles, Maxwell distribution of molecular speeds.

**Module 3 (10 hours)**

## Atomistic Simulation Techniques:

**Molecular Dynamics (MD):** Introduction, inter-atomic potential function, Lennard-Jones potential, MD simulation – equilibration and property evaluation, various types of potential functions, computational aspects, introduction to advanced topics.

**Monte Carlo (MC) Method:** Introduction, Metropolis algorithm, advanced algorithms for Monte Carlo simulations, comparison with Molecular Dynamics.

**Module 4 (10 hours)**

## Mesoscopic Simulation Techniques:

**Lattice Boltzmann Method (LBM):** Boltzmann equation, derivation of the hydrodynamic equation from Boltzmann equation, Lattice Boltzmann equation and LBM, applications of LBM.

**Dissipative Particle Dynamics (DPD):** Fundamentals of DPD simulations, timestep size and noise, repulsion parameter, approximate expressions for transport coefficients.

## Introduction to Multiscale methods and applications.

**References:**


1. Bird, G.A., Molecular Gas Dynamics and the Direct Simulation of Gas Flows, Oxford Science Publications, 1994
2. Goldstein, H., Poole, C., and Safko, J., Classical Mechanics, 3rd Edn., Pearson Education, 2006.
3. Bowley, R., and Sanches, M., Introductory Statistical Mechanics, 2nd Edn., Oxford Science Publications, 2007.
4. Ercolessi, F., A Molecular Dynamics Primer, Notes of Spring College in Computational Physics, ICTP, Trieste, June 1997 .
5. Liu, Wing Kam, Karpov, E.G., and Park, H.S., Nanomechanics and Materials, John Wiley & Sons, 2006.
6. Robert, K., Ian, H., Mark, G., Nanoscale Science and Technology, John Wiley & Sons, 200
7. Groot, R.D., and Warren, P.B., Dissipative particle dynamics: Bridging the Gap between Atomistic and Mesoscopic Simulation, *J. Chem. Phys*, **107**, 4423 (1997).

## EE6121: Data Acquisition & Signal Conditioning

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Total hours: 42 Hrs.**

**Module 1: Transducers & Signal Conditioning (11 hours)**

Data Acquisition Systems(DAS)- Introduction . Objectives of DAS . Block Diagram Description of DAS- General configurations - Single and multichannel DAS-Transducers for the measurement of motion, force, pressure, flow, level, dc and ac voltages and currents (CTs, PTs for supply frequency as well as high frequency, Hall Effect Current Sensors, High Voltage Sensors , Optosensors, Rogowski Coil, Ampflex Sensors etc.) - Signal Conditioning: Requirements - Instrumentation amplifiers: Basic characteristics . Chopped and Modulated DC Amplifiers-Isolation amplifiers - Opto couplers - Buffer amplifiers .Noise Reduction Techniques in Signal Conditioning- Transmitters .Optical Fiber Based Signal Transmission-Piezoelectric Couplers- Intelligent transmitters.

**Module 2: Filtering and Sampling (10 hours)**

Review of Nyquist.s Sampling Theorem-Aliasing . Need for Prefiltering-First and second order filters - classification and types of filters - Low -pass, High-pass, Band-pass and Band-rejection and All Pass: Butterworth, Bessel, Chebyshev and Elliptic filters . Opamp RC Circuits for Second Order Sections-Design of Higher Order Filters using second order sections using Butterworth Approximation-Narrow Bandpass and Notch Filters and their application in DAS. Sample and Hold Amplifiers

**Module 3: Signal Conversion and Transmission (10 hours)**

Analog-to-Digital Converters(ADC)-Multiplexers and demultiplexers - Digital multiplexer . A/D Conversion . Conversion Processes , Speed, Quantization Errors . Successive Approximation ADC . Dual Slope ADC . Flash ADC . Digital-to-Analog Conversion(DAC) . Techniques, Speed, Conversion Errors, Post Filtering- Weighted Resistor, R-2R, Weighted Current type of DACs-Multiplying Type DAC-Bipolar DACs- Data transmission systems-Schmitt Trigger-Pulse code formats- Modulation techniques and systems-Telemetry systems.

**Module 4: Digital Signal Transmission and Interfacing (11 hours)**

DAS Boards-Introduction . Study of a representative DAS Board-Interfacing Issues with DAS Boards, I/O vs Memory Addressing, Software Drivers, Virtual Instruments, Modular Programming Techniques for Robust Systems, Bus standard for communication between instruments - GPIB (IEEE-488bus) - RS-232C- USB-4-to-20mA current loop serial communication systems.Communication via parallel port . Interrupt-based Data Acquisition.Software Design Strategies-Hardware Vs Software Interrupts-Foreground/ background Programming Techniques- Limitations of Polling . Circular Queues

**References**

1. Ernest O Doeblin., Measurement Systems: Application and Design, McGraw Hill ( Int. edition) 1990

2. George C.Barney, Intelligent Instrumentation, Prentice Hall of India Pvt Ltd., New Delhi, 1988.

3. Ibrahim, K.E., Instruments and Automatic Test Equipment, Longman Scientific & Technical Group Ltd., UK, 1988.

4. John Uffrenbeck, The 80x86 Family ,Design, Programming, And Interfacing, Pearson Education , Asia, 2002

5. Bates Paul, Practical digital and Data Communications with LSI, Prentice Hall of India, 1987. 6. G.B. Clayton, .Operational Amplifiers, Butterworth &Co, 1992

7. A.K Ray, Advanced Microprocessors and Peripherals, Tata McGrawHill, 1991 8. Oliver Cage, .Electronic Measurements and Instrumentation., McGraw-Hill, ( Int. edition) 1975

## E6221: Distributed Generation

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**
**Module 1: (10 hours)**
Introduction to energy conversion .principle of renewable energy systems-technical and social implications; Solar energy. Overview of solar energy conversion methods. Solar radiation components-collector-measurements-estimation; Solar water heating-Calculation-Types-analysis-economics-Applications; Solar thermal power generation
**Module 2: (12 hours)**
Direct energy conversion (DEC)- DEC devices -Photo voltaic system-Solar cells- Cell efficiency-Limitations-PV modules-Battery back up-System design-Lighting and water pumping applications; Fuel cells. types- losses in fuel cell. applications; MHD generators- application of MHD generation.
**Module 3: (10 hours)**
Wind energy. characteristics-power extraction- types of wind machines .dynamics matching-performance of wind generators .wind mills -applications- economics of wind power
**Module 4: (10 hours)**
Biofuels- classification-biomass conversion process-applications; ocean thermal energy conversion systems; Tidal and wave power-applications; Micro and mini hydel power; Hybrid Energy Systems-implementation- case study.

**References**
1. J.N.Twidell & A.D.Weir-Renewable Energy Sources, University press,Cambridge, 2001
2. Sukhatme, S.P., Solar Energy -Principles of Thermal Collection and Storage, Tata McGraw-Hill, New Delhi 1997
3. Kreith, F., and Kreider, J.F., Principles of Solar Engineering, Mc-Graw-Hill Book Co. 2000
4. S.L. Soo ,Direct Energy Conversion , Prentice Hall Publication, 1963
5. James Larminie , Andrew Dicks , Fuel Cell Systems, John Weily & Sons Ltd, 2000
6. J. F. Manwell , J. G. McGowan, A. L. Rogers , Wind Energy Explained, John Weily & Sons Ltd 2009
7. E.J. Womack , MHD power generation engineering aspects , Chapman and Hall Publication, 2002
8. G.D. Rai, Non Conventional energy Sources, Khanna Publications ,New Delhi.1994
9. Loi Lei Lai, Tze Fun Chan, “Distributed Generation- Induction and Permanent Magnet Generators”, IEEE Press, John Wiley & Sons, Ltd., England. 2007.

## EE6302: Advanced Power Electronic Circuits

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**
**Module 1: (8 hours)**

Special Inverter Topologies - Current Source Inverter . Ideal Single Phase CSI operation, analysis and waveforms - Analysis of Single Phase Capacitor Commutated CSI.
Series Inverters . Analysis of Series Inverters . Modified Series Inverter . Three Phase Series Inverter

**Module 2: (12 hours)**

Switched Mode Rectifier - Operation of Single/Three Phase bilateral Bridges in Rectifier Mode . Control Principles . Control of the DC Side Voltage . Voltage Control Loop . The inner Current Control Loop.Single phase and three phase boost type APFC and control, Three phase utility interphases and control

**Module 3: (10 hours)**

Buck, Boost, Buck-Boost SMPS Topologies . Basic Operation- Waveforms - modes of operation – Output voltage ripple Push-Pull and Forward Converter Topologies - Basic Operation . Waveforms - Voltage Mode Control. Half and Full Bridge Converters . Basic Operation and Waveforms- Flyback Converter . discontinuous mode operation . waveforms . Control - Continuous Mode Operation . Waveforms

**Module 4: (12 Hours)**

Introduction to Resonant Converters . Classification of Resonant Converters . Basic Resonant Circuit Concepts . Load Resonant Converter . Resonant Switch Converter . Zero Voltage Switching Clamped Voltage Topologies . Resonant DC Link Inverters with Zero Voltage Switching . High Frequency Link Integral Half Cycle Converter.

**References**

1. Ned Mohan et.al “Power electronics : converters, applications, and design” John Wiley and Sons, 2006
2. Rashid “Power Electronics” Prentice Hall India 2007.
3. G.K.Dubey et.al “Thyristorised Power Controllers” Wiley Eastern Ltd., 2005, 06.
4. Dewan & Straughen “Power Semiconductor Circuits” John Wiley & Sons., 1975.
5. G.K. Dubey & C.R. Kasaravada “Power Electronics & Drives” Tata McGraw Hill., 1993.
6. IETE Press Book Power Electronics Tata McGraw Hill, 2003
7. Cyril W Lander “Power Electronics” McGraw Hill., 2005. 8. B. K Bose “Modern Power Electronics and AC Drives” Pearson Education (Asia)., 2007
9. Abraham I Pressman “Switching Power Supply Design” McGraw Hill Publishing Company., 2001.
10. Daniel M Mitchell “DC-DC Switching Regulator Analysis” McGraw Hill Publishing Company.- 1988

## EE6508: High Voltage Testing Techniques

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisites-Nil**

**Module 1: (11 hours)**

Objectives of high voltage testing - classification of testing methods- self restoration and non-self restoration systems-standards and specifications - measurement techniques - Diagnostic testing - online measurement.

**Module 2: (11 hours)**

Determination of probability values - Distribution function of a measured quantity, confidence limits of the mean values of disruptive discharges - ‘Up and Down’ method for determining the 50% disruptive discharge voltage - multi stress ageing - life data analysis.

**Module 3: (9 hours)**

Testing of insulators, bushings, air break switches, isolators, circuit breakers, power transformers, voltage transformers, current transformers, surge diverters, cable – testing methodology - recording of oscillograms - interpretation of test results.

**Module 4: (11 hours)**

Dynamic properties of dielectrics-dielectric loss and capacitance measurement - partial discharge measurements - PD equivalent model – PD quantities - Digital PD instruments and measurements - acoustic emission technique and UHF Techniques for PD identification - Corona and RIV measurements. Artificial Pollution tests- salt-fog method, solid layer method - Dimensions of High voltage laboratory, equipment - fencing, earthing and shielding - circuits for high voltage experiments.

**References**


1. Dieter Kind, Kurt Feser, “High Voltage Test Techniques”, SBA Electrical Engineering Series, New Delhi, 1999.
2. Naidu M.S. and Kamaraju V., “High voltage Engineering”, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2009.
3. Kuffel E., Zaengl W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsevier India P Ltd, 2005.
4. Gallagher T.J. and Pearmain A., “High Voltage Measurements, Testing and Design”, John Willey & Sons, New York, 1983.
5. IS, IEC and IEEE standards for Dielectric Testing of High Voltage Apparatus.
   Nelson W., “Applied Life Data Analysis”, John Wiley and Sons, New York, 1982.
6. Kennedy W., “Recommended Dielectric Tests and Test Procedures for Converter Transformer and Smoothing Reactors”, IEEE Transactions on Power Delivery, Vol.1, No. 3, pp. 161-166, 1986.

7. IEC – 60270, “HV Test technique – Partial Discharge Mechanism”, 3rd Edition, December 2000.
8. Judd M.D., Liyang and Ian BB Hunter, “P.D Monitoring of Power Transformers using UHF Sensors” Vol.21, No.2, pp. 5-14, 2004.

## EE6507: High Voltage Power Transformers and Circuit Breakers

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**

**Total hours: 42 Hrs.**

**Module 1: (10 hours)**

HV power transformers, principle and equivalent circuit, Magnetic characteristics-Excitation characteristics, over excitation performance, Inrush current.
Impedance characteristics, Reactance calculation, Losses in transformers-eddy current loss, hysteresis loss and stray loss in power transformers.

**Module 2: (11 hours)**

Short circuit forces, failure mode due to radial and axial forces, Short circuit test, Effect of inrush current.
Surge phenomenon-initial voltage distribution-ground capacitance calculations-capacitance of winding, inductance calculation- standing and traveling wave theory, Method for analysis of impulse distribution.

**Module 3: (10 hours)**

Impulse testing, diagnostics and condition monitoring of transformers, Conventional tests, Dissolved Gas Analysis, Partial Discharge Diagnostics, Degree of Polymerisation and Furan Analysis, Time domain and frequency domain dielectric response method.

**Module 4: (11 hours)**

Introduction to HV switching devices, electric arcs, short circuit currents, TRV, CB types, air, oil and SF6 CB, short circuit testing.

**References**

1. S.V. Kulkarni, S.A. Khaparde, “Transformer Engineering: Design, Technology, and Diagnostics”, Second Edition, CRC Press Taylor and Francis Group, 2012.
2. Bernard Hochart, Power Transformer Handbook, Butterworth, 1987.
3. The J & P Transformer Book, 12th Edn, M J Heathcote, Newnes, 1998.
4. Transformers, Bharat Heavy Electricals Limited, Tata McGraw Hill, 2001.
5. Blume, L.F., and Boya Jian, Transformer Engineering, John Wiley and Sons, 1951.
6. Garzon, R.D., HV Circuit Breakers – Design and Applications, Marcel and Dekker NY, 1996.
7. Flurscheim, C.H., Power Circuit Breaker: Theory and Design, Peter Peregrinus Ltd., 1975.
8. Ryan, H.M., and Jones G.R., SF6 Circuit Breaker, Peter Peregrinus Ltd., 1989.

**EE6204: Digital Protection of Power Systems**

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

**Module 1: (8 hours)**
Protective Relaying - Qualities of relaying - Definitions - Codes- Standards; Characteristic Functions; Classification –analog-digital- numerical; schemes and design-factors affecting performance –zones and degree of protection; faults-types and evaluation; Instrument transformers for protection.

**Module 2: (12 hours)**
Basic elements of digital protection –signal conditioning- conversion subsystems- relay units-sequence networks-fault sensing data processing units- FFT and Wavelet based algorithms: least square and differential equation based algorithms-travelling wave protection schemes;
Relay Schematics and Analysis- Over Current Relay- Instantaneous/Inverse Time –IDMT Characteristics; Directional Relays; Differential Relays- Restraining Characteristics; Distance Relays: Types- Characteristics.

**Module 3: (14 hours)**
Protection of Power System Equipment - Generator, Transformer, Transmission Systems, Busbars, Motors; Pilotwire and Carrier Current Schemes;
System grounding –ground faults and protection; Load shedding and frequency relaying; Out of step relaying ; Re-closing and synchronizing

**Module 4: (8 hours)**
Integrated and multifunction protection schemes -SCADA based protection systems- FTA; Testing of Relays.

**References**
1. A T John and A K Salman- Digital protection for power systems-IEE power series-15, Peter Peregrines Ltd,UK,1997
2. C.R. Mason, The art and science of protective relaying, John Wiley &sons, 2002
3. Donald Reimert, ,Protective relaying for power generation systems, Taylor & Francis-CRC press 2006
4. Gerhard Ziegler-Numerical distance protection, Siemens, 2nd ed, 2006
5. A.R.Warrington, Protective Relays, Vol .1&2, Chapman and Hall, 1973
6. T S.Madhav Rao, Power system protection static relays with microprocessor applications, Tata McGraw Hill Publication, 1994
7. Power System Protection Vol. I, II , III&IV, The Institution Of Electrical Engineers, Electricity Association Services Ltd., 1995
8. Helmut Ungrad , Wilibald Winkler, Andrzej Wiszniewski, Protection techniques in electrical energy systems, Marcel Dekker, Inc. 1995
9. Badri Ram , D.N. Vishwakarma, Power system protection and switch gear, Tata McGraw Hill, 2001
10. Blackburn, J. Lewis ,Protective Relaying, Principles and Applications, Marcel Dekker, Inc., 1986. Anderson, P.M, Power System Protection,. McGraw-Hill, 1999

11. Singh L.P ,Digital Protection, Protective Relaying from Electromechanical to Microprocessor, John Wiley & Sons, 1994
12. Wright, A. and Christopoulos, C, Electrical Power System Protection,. Chapman & Hall, 1993,
13. Walter A. Elmore, J. L. Blackburn, Protective Relaying Theory and Applications, ABB T&D Co. Marcel Dekker, Inc. 2004
14. Arun G. Phadke, James S. Thorp, Computer Relaying for Power Systems, Marcel Dekker, Inc 2009

## EE6509: Electromagnetic Interference and Compatibility

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

**Module 1: (11 hours)**
BASIC CONCEPTS Definition of EMI and EMC with examples, Classification of EMI/EMC - CE, RE, CS, RS, Units of Parameters, Sources of EMI, EMI coupling modes - CM and DM, ESD Phenomena and effects, Transient phenomena and suppression

**Module 2: (11 hours)**
EMI MEASUREMENTS, Basic principles of RE, CE, RS and CS measurements, EMI measuring instruments- Antennas, LISN, Feed through capacitor, current probe, EMC analyzer and detection t6echnique open area site, shielded anechoic chamber, TEM cell.

**Module 3: (9 hours)**

EMC STANDARD AND REGULATIONS National and Intentional standardizing organizations- FCC, CISPR, ANSI, DOD, IEC, CENEEC, FCC CE and RE standards, CISPR, CE and RE Standards, IEC/EN, CS standards, Frequency assignment - spectrum conversation.

**Module 4: (11 hours)**
EMI CONTROL METHODS AND FIXES Shielding, Grounding, Bonding, Filtering, EMI gasket, Isolation transformer, opto isolator.
EMC DESIGN AND INTERCONNECTION TECHNIQUES Cable routing and connection, Component selection and mounting, PCB design- Trace routing, Impedance control, decoupling, Zoning and grounding

**References**

1. Keiser – Principles of Electromagnetic Compatibility – Artech House – 3rd Edition – 1994
2. Donwhite Consultant Incorporate – Handbook of EMI / EMC – Vol I – 1985
3. Clayton R.Paul – Introduction to Electromagnetic compatibility – John Wiley & Sons 1992

## EE 6510: Pulsed Power Engineering

| L | T | P | C |
|---|---|---|---|
| **3** | **0** | **0** | **3** |

**Pre-requisite: Nil**
**Total hours: 42 Hrs.**

**Module 1: (11 hours)**
Introduction to pulsed power systems (examples and applications), Energy storage (capacitive, inductive, kinetic, chemical), Voltage multiplier circuits (Marx generators, Blumlein generators, and spiral generators, etc.), Transmission lines and pulse forming networks.

**Module 2: (11 hours)**
Insulation and breakdown (gas, vacuum, liquid, solid, and surface), Grounding, shielding, safety, Pulsed power materials, High speed diagnostics (voltage, current, plasma, magnetic field, etc.)

**Module 3: (9 hours)**
Computer simulations, High power switches: spark gaps, low pressure switches, liquid and solid state switches, solid stage switches, magnetic switches, opening switches, Electromagnetic field analysis of pulsed power circuits

**Module 4: (11 hours)**
Applications : High Power Microwaves, mass drivers, pollution control, particle accelerators, lasers, manufacturing, Nuclear electromagnetic fields, High voltage hazards and accidents.

**References**

1. Pai and Zhang, *Introduction to High Power Pulse Technology*, World Scientific Publishing, 1995.
2. Martin et al., *J. C. Martin on Pulsed Power*, Plenum Press, 1996.
3. G.A. Mesyats, *Pulsed Power*, Kluwer Academics/Plenum 2005.

## EE6401: Energy Auditing & Management

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Pre-requisite: Nil**

**Total hours: 42 Hrs**

Objective: Understanding, analysis and application of electrical energy management-measurement and accounting techniques-consumption patterns- conservation methods-application in industrial cases.

**Module 1: (9 hours)**

System approach and End use approach to efficient use of Electricity; Electricity tariff types; Energy auditing: Types and objectives-audit instruments- ECO assessment and Economic methods-specific energy analysis-Minimum energy paths-consumption models-Case study.

**Module 2: (11 hours)**

Electric motors-Energy efficient controls and starting efficiency-Motor Efficiency and Load Analysis- Energy efficient /high efficient Motors-Case study; Load Matching and selection of motors.

Variable speed drives; Pumps and Fans-Efficient Control strategies- Optimal selection and sizing -Optimal operation and Storage; Case study

**Module 3: (11 hours)**

Transformer Loading/Efficiency analysis, Feeder/cable loss evaluation, case study.

Reactive Power management-Capacitor Sizing-Degree of Compensation-Capacitor losses-Location-Placement-Maintenance, case study.

Peak Demand controls- Methodologies-Types of Industrial loads-Optimal Load scheduling-case study.

Lighting- Energy efficient light sources-Energy conservation in Lighting Schemes- Electronic ballast-Power quality issues-Luminaries, case study.

**Module 4: (11 hours)**

Cogeneration-Types and Schemes-Optimal operation of cogeneration plants-case study;

Electric loads of Air conditioning & Refrigeration-Energy conservation measures- Cool storage. Types-Optimal operation-case study; Electric water heating-Gysers-Solar Water Heaters- Power Consumption in Compressors, Energy conservation measures; Electrolytic Process; Computer Controls- software-EMS

**References**


1. Handbook on Energy Audit and Environment Management , Y P Abbi and Shashank Jain, TERI, 2006

2. Handbook of Energy Audits Albert Thumann, William J. Younger, Terry Niehus, 2009

3. Giovanni Petrecca, .Industrial Energy Management: Principles and Applications., The Kluwer international series -207,1999

4. Anthony J. Pansini, Kenneth D. Smalling, .Guide to Electric Load Management., Pennwell Pub; (1998)

5. Howard E. Jordan, .Energy-Efficient Electric Motors and Their Applications., Plenum Pub Corp; 2nd edition (1994)

6. Turner, Wayne C., .Energy Management Handbook., Lilburn, The Fairmont Press, 2001

7. Albert Thumann , .Handbook of Energy Audits., Fairmont Pr; 5th edition (1998)

8. IEEE Bronze Book- .Recommended Practice for Energy Conservation and cost effective planning in Industrial facilities., IEEE Inc, USA. 2008

9. Albert Thumann, P.W, -.Plant Engineers and Managers Guide to Energy Conservation. - Seventh Edition-TWI Press Inc, Terre Haute, 2007

10. Donald R. W., .Energy Efficiency Manual., Energy Institute Press, 1986

11. Partab H., 'Art and Science of Utilisation of Electrical Energy', Dhanpat Rai and Sons, New Delhi. 1975

12. Tripathy S.C.,'Electric Energy Utilization And Conservation', Tata McGraw Hill, 1991

13. NESCAP-Guide Book on Promotion of Sustainable Energy Consumption, 2004

14. IEEE Bronze Book, IEEE STD 739

15. IEEE Recommended Practices for Energy Management in Industrial and Commercial Facilities

16. Guide to Energy Management, Sixth Edition , Barney L. Capehart (Author), Wayne C. Turner (Author), William J. Kennedy, Fairmont Press; 6 edition (April 23, 2008)

17. Energy Efficiency Manual: for everyone who uses energy, pays for utilities, designs and builds, is interested in energy conservation and the environment, Donald R. Wulfinghoff, Energy Institute Press (March 2000)

18. Handbook of Energy Audits, Seventh Edition, Albert Thumann., William J. Younger, Fairmont Press; 7 edition (November 12, 2007)

19. Certified Energy Manager Exam Secrets Study Guide: CEM Test Review for the Certified Energy Manager Exam CEM Exam Secrets Test Prep Team Mometrix Media LLC (2009)

20.Handbook of Energy Engineering, Sixth Edition Albert Thumann , D. Paul Mehta Fairmont Press; 6 edition (June 24, 2008)