CURRICULUM AND SYLLABI

M.Tech.

in

HIGH VOLTAGE ENGINEERING

(With effect from Academic Year 2018-2019)

DEPARTMENT OF ELECTRICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
CALICUT - 673601

DEPARTMENT OF ELECTRICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

Vision of the Department of Electrical Engineering

To be nationally and internationally recognized in providing electrical engineering education and training candidates to become well-qualified engineers who are capable of making valuable contributions to their profession and carrying out higher studies successfully.

Mission of the Department in pursuance of its vision

To offer high quality programs in the field of electrical engineering, to train students to be successful both in professional career as well as higher studies and to promote excellence in teaching, research, collaborative activities and contributions to the society.

The Program Educational Objectives (PEOs) of M. Tech.Programme in HIGH VOLTAGE ENGINEERING

PEO1	To equip the electrical engineering graduates with enhanced knowledge and skills in the area of High Voltage Engineering so as to excel in various sectors of modern power industry/utility and/or teaching and/or higher education and/or research.
PEO2	To transform electrical engineering graduates to expert High Voltage engineers so that they could comprehend, analyze, design and create novel products and strategic solutions to real life problems in the area of High Voltage Engineering that are technically sound, economically feasible and socially acceptable.
PEO3	To make the engineering graduates capable of maintaining lifelong learning and up keeping professional ethics and social values while addressing the technical and social challenges.
PEO4	To improve the communication skills and willingness to work in groups and to develop multidisciplinary approach in problem solving.

The Programme Outcomes (POs) of
M. Tech.Programme in HIGH VOLTAGE ENGINEERING

PO1	Ability to independently carry out research /investigation and development work to solve practical problems
PO2	Ability to write and present a substantial technical report/document
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
PO4	Ability to utilize the acquired knowledge to design and develop new techniques in order to tackle the problems pertaining to high voltage systems and also take up administrative challenges including the management of projects related to High Voltage Systems having multidisciplinary nature.
PO5	Willingness and ability to upkeep professional ethics and social values while carrying out the responsibilities as a High Voltage engineer/researcher in devising solutions to real life engineering problems in an independent manner.

Curriculum for M. Tech. Programme in High Voltage Engineering

This Programme is offered in four semesters.The structure of M.Tech.Programme shall have the following Course categories:

Semester 1

Course Code	Course Title	L	T	P/S	C
MA6003D	Mathematical Methods for Power Engineering	3	-	-	3
EE6501D	High Voltage Engineering	3	-	-	3
EE6503D	Power System Transients	3	-	-	3
EE6301 D	Power Electronic Circuits	3	-	-	3
	Elective -1	3	-	-	3
EE6591D	High Voltage Laboratory	-	-	2	1
EE6593 D	Seminar	-	-	2	1
Total		15	-	-	17

Semester 2

Course Code	Course Title	L	T	P/S	C
EE6502D	Computational Electromagnetics	3	-	-	3
EE6504D	Physics of Dielectrics	3	-	-	3
EE6506D	EHV Power Transmission	3			3
	Elective -1	3	-	-	3
	Elective -2	3	-	-	3
	Elective -3	3	-	-	3
EE6592 D	Mini Project	-	-	2	1
Total		18	-	-	19

Note: The students shall undergo Industrial Training in a reputed industry / R&D organization during summer vacation.

Semester 3

Course Code	Course Title	L	T	P/S	C
EE7591D	Project –Part 1	-	-	20	10
Total		-	-	20	10

Semester 4

Course Code	Course Title	L	T	P/S	C
EE7592D	Project –Part 2	-	-	28	14
Total		-	-	28	14

LIST OF ELECTIVES

Sl. No	Code	Title	Credits
1	EE6521D	HVDC Transmission	3
2	EE6522D	High Voltage Power Transformers and Circuit Breakers	3
3	EE6523D	Condition Monitoring of Power Equipment	3
4	EE6524D	Electromagnetic Interference and Compatibility	3
5	EE6525D	Pulsed Power Engineering	3
6	EE 6526D	High Voltage Testing Techniques	3
7	EE6101D	Systems Theory	3
8	EE6103D	Measurements and Instrumentation	3
9	EE6104D	Advanced Instrumentation	3
10	EE6105D	Digital Control: Theory and Design	3
11	EE6121D	Data Acquisition and Signal Conditioning	3
12	EE6122D	Biomedical Instrumentation	3
13	EE6140D	Advanced Soft Computing Techniques	3
14	EE6201D	Computer Methods in Power System Analysis	3
15	EE6202D	Power System Dynamics and Control	3

16	EE6203D	Distributed Generation & Microgrid	3
17	EE6204D	FACTS and Custom Power	3
18	EE6206D	Digital Protection of Power Systems	3
19	EE6221D	Power Quality Issues and Remedial Measures	3
20	EE6222D	Wide Area Monitoring and Control of Power Systems	3
21	EE6223D	Power System Planning and Reliability	3
22	EE6224D	Distributed Processing of Power Systems	3
23	EE6226D	Hybrid and Electric Vehicles	3
24	EE6302D	Advanced Power Electronic Circuits	3
25	EE6304D	Modern Digital Signal Processors	3
26	EE6306D	Power Electronic Drives	3
27	EE6323D	Digital Simulation of Power Electronic Systems	3
28	EE6327D	Implementation of DSP Algorithms	3
29	EE6329D	Advanced Microprocessor Based Systems.	3
30	EE6401D	Energy Auditing & Management	3
31	EE6405D	Artificial Intelligence & Automation	3
32	EE6421D	Smart Grid Technologies and Applications	3
33	EE6422D	Engineering Optimization and Algorithms	3
34	EE6426D	Distribution System Management and Automation	3
35	EE6428D	SCADA Systems and Applications.	3
35	EE6429D	Wireless and Sensor Networks	3
37	EE6430D	Network and Data Security	3
38	EE6432D	Advanced Algorithms and Data Structure Analysis	3
39	EE6434D	Internet of Things and Applications	3
40	EE6436D	Industrial Load Modelling & Control	3
41	EC6104D	Electromagnetic Compatibility	4
42	EC6401D	Linear Algebra for Signal Processing	3
43	EC6434D	Linear & Non Linear Optimization	4
44	NS6101D	Structure of Nanomaterials	3
45	NS6111D	Spectroscopic Characterisation of Nanomaterials	3
46	NS6112D	Experimental Techniques in Nanotechnology	3

47	NS6122D	Nano Materials for Energy and Environment	3
48	NS6124D	Computational Nanotechnology	3

Notes:

1. A minimum of **60** credits have to be earned for the award of M. Tech Degree in this Programme.
2. Communicative English and Audit courses are optional.
3. Industrial Training during summer is optional.
4. List of Electives offered in each semester will be announced by the Department.
5. Any other PG level course of NITC approved by senate offered in the Institute can also be credited as elective with the prior approval from the Programme Coordinator.

MA6003D MATHEMATICAL METHODS FOR POWER ENGINEERING

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: Apply notions of vector spaces and linear transformations in engineering problems
CO2. Diagonalise linear operators and quadratic forms.
CO3: Handle various linear programming problems and apply the simplex method for solving linear programming problems in various fields of science and technology.
CO4: Solve constrained and unconstrained nonlinear programming problems.
CO5: Apply the concept of random variables, functions of random variable and their probability distribution in problems involving uncertainty.
CO5: Classify stochastic processes using autocorrelation function.

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 (10hours)

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 (9 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 ed., 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 ed., PHI, 2002.
4. J. Medhi, '*Stochastic Processes*', New Age International, New Delhi., 1994
5. A Papoulis*, 'Probability, Random Variables and Stochastic Processes'*, 3rd ed., McGraw Hill, 2002
6. John B Thomas, '*An Introduction to Applied Probability and Random Processe's*, John Wiley, 2000
7. Hillier F S and Liebermann G J, '*Introduction to Operations Research*', 7th ed., McGraw Hill, 2001
8. Simmons D M, '*Non Linear Programming for Operations Research*', PHI, 1975

EE6501D HIGH VOLTAGE ENGINEERING

Prerequisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the need for the generation of high AC, DC and impulse voltage.
CO2: Describe the principles behind generation of high DC, AC and impulse voltages.
CO3: Develop equivalent circuit models of the different high voltage generators.
CO4: Understand the principle of high voltage measurement systems.
CO5: Identify the insulation used in power equipment and their classification based on temperature.
CO6: Compute the breakdown strength of gas-filled insulation systems with simple geometries.
CO7: Estimate the breakdown strength of contaminated liquids and solids

Module 1: (11hours)

Requirements of HV generation in laboratory, Generation of High voltages, AC voltages: Testing transformers-Series resonance circuits; DC voltages: symmetric and asymmetric voltage doubler circuits-electrostatic machines.
Generation of Impulse voltages and currents: single stage and multistage circuits-wave shaping-modeling of impulse generator circuit-triggering and control of impulse generators. Generation of switching surge voltage and currents.
Simulation of AC, DC and Impulse Voltage/Current generation circuits.

Module 2: (10hours)

Measurement of high voltages: Sphere gaps, factors affecting sphere gap measurements, correction factors.
Measurement of high AC voltage: Capacitance voltage dividers, Chubb-Fortescue method, CVT, electrostatic voltmeters.
Measurement of high DC voltage: Resistive voltage dividers, Generating voltmeter.
Measurement of impulse voltage: Capacitance divider, Impedance matching.
Measurement of transient currents: Resistive shunt, Magnetic coupling, Hall Effectcurrent transducers, Integrating and differentiating type Rogowski coils.
Digital techniques in HV measurements, DSO.

Module 3: (8hours)

Introduction to solid, liquid and gaseous insulators used in power equipment. Classifications of insulation based on temperature withstand limits, dielectric losses, ageing of insulation materials (paper –press board) and remaining life analysis.
Applications of nanofilled materials for outdoor and indoor insulation.

Module 4: (10 hours)

Introduction to solid, liquid and gaseous dielectrics.Breakdown in gas and gas mixtures-breakdown in uniform and non uniform fields-Paschen's 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. Kuffel and Zaengl, '*High Voltage Engineering*', Newnes, 2nd edition, 2000.
2. M. S. Naidu, V. Kamaraju, '*High Voltage Engineering*', McGraw-Hill, 1995.

3. Subir Ray, *'An Introduction to High Voltage Engineering'*, PHI Learning Private Limited; 2nd edition,2013.
4. Kuffel and Abdulla. M. '*High Voltage Engineering*', Pergamon press, 1998.
5. Wadhwa C L., '*High Voltage Engineering*', Wiley Eastern Limited, NewDelhi, 1994.
6. T. J. Gallagher, A.J Pearmain, '*High Voltage- Measurement Testing and Design*', John Wiley & Sons, 1984.

EE6503D POWER SYSTEM TRANSIENTS

Pre-requisite: Nil

Total hours: 39

L	T	P	C
3	0	0	3

Course outcomes:

CO1: Understand the source and characteristics of lightning, switching, and temporary overvoltages.
CO2: Understand travelling wave propagation on transmission lines.
CO3: Understand the critical switching transient situations.
CO4: Be able to set up differential equations for RLC circuits and solve it via stationary and transient solutions.
CO5: Select various protective devices and insulation level.

Module 1: (10 hours)

Analysis and modelling of electromagnetic transients in power system: 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- Modelling for computation of electromagnetic transients-wavelet technique for determining fault in transformer.

Module 2:(10 hours)

Temporary, Lightning and Switching and overvoltages:
Temporary overvoltages: line dropping, load rejection, over voltages induced by fault, Ferranti effect, Ferromagnetic resonance.
Switching overvoltages: Energizing transients - closing and re-closing of lines –Switching of cables and capacitor banks, Short line or kilometric fault, Switching HVDC lines.
Lightning: Physical phenomena of lightning – Interaction between lightning and power system – Influence of tower footing resistance and earth Resistance- indirect lightning- protection by ground wires.

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- Behaviour of transformer windings for surges- Protection of tapping winding of transformer under transmission line fault due to resonance.

Module 4:(9hours)

Insulation coordination:
Basics of Insulation Coordination • Definitions, principle of insulation coordination, Volt-time curves-Rated withstand voltage levels and clearances, relevant standard. Insulation Coordination as applied to Electrical Installation • Over-voltage protective devices, breakdown consequences, reduction of risks and levels of over-voltage, installation of surge arrestor.

References:

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

2. Juan A. Matinez-velasco, “*Power system Transients- Parameter determination*”, CRC press, 2010
3. Philip C. Magnusson, Gerald C. Alexander, Vijai K Tripathi, Andreas Weisshaar, “*Transmission lines and wave propagation*”, CRC press, 2001.
4. Arieh L. Shenkman, “*Transient analysis of Electric power circuits Handbook*”, Springer, 2005.

EE6301D POWER ELECTRONIC CIRCUITS

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:
CO1: Analyse and design the Diode rectifiers and filters circuits
CO2: Design and implement various types of controlled rectifiers
CO3: Explain about various PWM techniques of 2-level DC to AC converters
CO4: Evaluate and design inverters with advanced PWM techniques
CO5: Design current controlled voltage source inverters

Module 1: Line Frequency Uncontrolled and Controlled Rectifiers and Inverters (13 hours)

C / LC filter Design for Single Phase diode rectifiers. Three Phase half wave rectifier with resistive load . Three phase full wave rectifier .Double Y type rectifier.Three Phase Rectifier Circuits. Input Line Current Harmonics and power factor. Line Notching and its control.
Single Phase: Half Wave Controlled Rectifier with R, RL, RLE loads, With Freewheeling diode.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 2: Switch-Mode dc-ac Inverters (13 hours)

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.3rd Harmonic injection to enhance the source utilisation.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 3: Introduction to high power converters (13 hours)

Converters for High Power Applications: Standard Modulation Strategies - Programmed Harmonic Elimination. Multi-Pulse Converters and Interface Magnetics - Space Vector Modulation – Minimum ripple current PWM method. 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 ‘*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 ‘*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.

EE6591D HIGH VOLTAGE LABORATORY

Pre-requisites: Nil

L	T	P	C
0	0	2	1

Total hours: 26

Course Outcomes:
CO1: Estimate the AC, DC and Impulse breakdown strength of solid insulators
CO2: Determination of the breakdown strength of transformer oil
CO2: Measurement of dielectric parameters of a solid dielectric.
CO3: Familiarization with Matlab software and field plotting.
CO4: Design a DC/ impulse voltage generator circuit and simulate using Pspice/Pscad
CO5: Experimentally verify the travelling wave phenomena on transmission lines with different terminations
CO6: Measure partial discharge and plot the ϕqn pattern
CO7: Preparation of polymer nanocomposite and plotting the dielectric characteristics
CO8: Understand the electric field distribution for various electrode arrangements.

List of Experiments:

1. AC, DC AND IMPULSE BREAKDOWN TEST OF SOLID INSULATION
2. OIL BREAKDOWN TEST USING OIL TEST KIT
3. CAPACITANCE AND TANδ MEASUREMENT OF INSULATOR.
4. DIELECTRIC CHARACTERITICS OF SOLID INSULATING MATERIAL USING IMPEDANCE ANALYSER
5. MEASUREMENT OF INSULATION RESISTANCE OF CABLE
6. MAPPING OF ELECTRIC FIELD LINES BETWEEN TWO CHARGES USING MATLAB
7. SIMULATION OF DC/IMPULSE VOLTAGE GENERATION CIRCUITS USING PSPICE/PSCAD.
8. TRAVELLING WAVE CHARACTERISTICS WITH DIFFERENT LINE TERMINATIONS USING PSCAD.
9. PLOTTING Φ-Q-N PATTERN FOR CORINA DISCHARGE USING PARTIAL DISCHARGE DETECTOR
10. PREPARATION OF EPOXY NANOCOMPOSITE
11. PLOTTING THE ELECTRICAL FIELD DISTRIBUTION IN AN INSULATING MATERIAL USING COMSOL (WITH AND WITHOUT VOID).
12. FIELD DISTRIBUTION BETWEEN PLATES OF A PARALLEL PLATE CAPACITOR USING ANSYS.

References:

1. Relevant IS and IEC standards.
2. Kuffel and Zaengl. '*High Voltage Engineering'*, Newnes, 2000.

EE6593D SEMINAR

Pre-requisites: Nil

L	T	P	C
0	0	2	1

Total hours: 26

Course outcomes:

CO1: Identify emerging technologies in the field of High Voltage Engineering, in the absence of a text book, to summarize and review them.
CO2: Develop presentation and discussion skills of various cutting edge technologies identified.
CO3: Impart listening, argumentative and critical thinking skills by making the students take part in the discussion.
CO4: Prepare a neat technical report of the presented topic.

Individual students will be asked to choose a topic in any field of High Voltage Engineering, preferably the recent development and advances and give seminar on the topic for about one hour. A committee consisting of at least two faculty members will assess the presentation of the seminars and award the marks to the students. Each student will be asked to submit two copies of a write up of the seminar talk – one copy will be returned to the student after duly certifying by the Chairman of the assessing committee and the other copy will be kept in the departmental library.

EE6502D COMPUTATIONAL ELECTROMAGNETICS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: Understand and independently apply standard methods for electromagnetic wave propagation.

CO2: Develop new methods and software for finite difference and finite element differential equation models as well as charge simulation method for frequency domain models.

CO3: Use commercial application software with insight into fundamental properties and limitations

CO4: Apply the techniques of numerical computation for the modelling of electrical apparatus for the impulse and power frequency voltages.

Module 1: (10 hours)

Review of basic field theory – electric and magnetic fields – Maxwell's equations –Laplace, Poisson and Helmholtz equations – principle of energy conversion – force/torque calculation – Electro thermal formulation.

Module 2: (10 hours)

Limitations of the conventional design procedure need for the field analysis based design, problem definition and solution by analytical methods-direct integration method – separation of variables method –method of images, solution by numericalmethods- Finite Difference Method- 1D and 2D planar and axial symmetry problem, Charge Simulation Method- 3D and 2D axial symmetry problem.

Module 3: (10 hours)

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

Module 4: (9 hours)

Resistive and capacitive field computation-Electromagnetic modelling of Insulators-Bushings,Transformers –Rotating machines for power frequency and impulse voltages.

References

1. S. Chakravorti, '*Electric Field Analysis'*, published by CRC Press (Taylor & Francis), USA, 2015, 1st Ed.
2. Karl E. Lonngren, Sava V. Savov, Randy J. Jost, *'Fundamentals of Electromagnetics with MATLAB'*, 2nd edition, SciTech Publishing, Inc., 2007.
3. George W. Pan, *'Wavelets in Electromagnetics and Device Modelling'*, Wiley.
4. JaanKiusalaas, '*Numerical Methods in Engineering with Python'*, Cambridge University Press, 2nd edition, 2010.
5. Chen, Cao and Mittra, *'Multiresolution Time Domain Scheme for Electromagnetic Engineering'*, Wiley, 1stedition ,2005.
6. A Daniel G. Swanson, Wolfgang J.R. Hoefer, *'Microwave circuit modelling using electromagnetic field simulation'*, Artech House, 2003.
7. Sergey N. Makarov, '*Antenna and EM Modelling with Matlab'*, Wiley, 2002.

EE6504D PHYSICS OF DIELECTRICS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: Gain knowledge about the different types of polymers used as dielectric materials in various power equipment

CO2: Describe polarization processes with suitable relaxation functions in time domain and complex permittivity functions in frequency domain

CO3: Identify the fundamental physical mechanism behind given relaxation/permittivity curves.

CO4: Analyze the information contained in the temperature dependence of dielectric materials.

CO5: Explain the different mechanisms that may lead to dielectric breakdown

CO6: Estimate the life of the insulation subjected to electrical and thermal stress by graphical and analytical method.

CO7: Identify partial discharge in dielectric materials by electrical, UHF and acoustic methods of measurement

Module 1: (8 hours)

Introduction to dielectrics and electrical insulation systems used in high voltage power apparatus: gaseous, vacuum, liquid, solid and composite insulation. Polymers as dielectrics in various electrical equipment, polymer structure and morphology, classification of polymers, filled polymers for HV applications.Introduction to electrical degradation in nanodielectrics – treeing, partial discharge, tracking & erosion.

Module 2: (11 hours)

Behaviour of dielectrics in electric fields, electronic, ionic, dipolar and interfacial polarization, non linearity between D and E. Behaviour of dielectric in time varying field, relaxation mechanism, permittivity and dielectric loss, space charge in dielectrics.

Module 3: (10 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. Effect of moisture on cellulose aging.

Module 4: (10 hours)

Ageing and failure due to Partial Discharge:
Basics of Partial Discharge: Partial Discharge – how and where, Generation of PD pulses, Stress mechanisms activated by PD.

Electrical Method of PD Detection: Goals of PD measurement, PD detection methods, Electrical method of PD detection and the relevant standard, Quantities related to PD measurement, External interference and noise elimination.

UHF and Acoustic Methods of PD Detection: UHF sensors, Detection of PD by UHF sensors, On-line UHF PD measurement, Detection of PD by acoustic sensors, non-removable and removable installation of sensors.

References:

1. T. S.Ramu and Chakradhar Reddy, '*Reliability and Life estimation of Power Equipmen"*", New Age International 2009.
2. Sivaji Chakravorti, DebangshuDey, Biswendu Chatterjee, "*Recent trends in the condition monitoring of transformers, Theory, Implementation and Analysis*", Springer Verlag London 2013.
3. Bottcher C.J.F., *Theory of Electric Polarisation*, Elsevier Publication, 1962.
4. Kuffel and Zaengl*High Voltage Engineering*, Newnes,2000.
5. Wadhwa C. L., *High Voltage Engineering*, Wiley Eastern Limited, NewDelhi,1994
6. Relevant IS standards and IEC standards
7. Mann N.R. Schafer R.E. and Singpurwalla N.D., *Methods of Statistical Analysis and Life Data*, John Wiley and Sons, New York, 1974.
8. B. Tareev, "*Physics of Dielectric Materials",* Mir Publishers Moscow, 1979

EE6506D EHV POWER TRANSMISSION

Pre-requisite-Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: To understand the need of EHV and UHV systems.
CO2: To know methods of governance on the line conductor design, line height and phase.
CO3: To know the different types of substation earthing schemes
CO4: To know the fundamentals of a GIS and GIL

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-sequence inductance and capacitance-line parameters for modes of propagation-Temperature rise of conductors and current carrying capacity.

Module 2: (10 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:(9 hours)

Functional Requirements of Earthing System, Equipment Earthing, Neutral Point Earthing, Substation Earthing System, Dimensioning of Earth Conductors, Step Potential and Touch Potential, Earth Mat, Resistance of Earthing System, Values of Soil Resistivity, Fencing, Procedure of Laying Earthing ,Shielding by wires and masts.

Module 4: (2 hours)

HVDC Transmission: HVDC transmission, kind of dc links, Comparison between AC and DC transmissions Applications of HVDC transmission. Power modulation and power control of HVDC lines.

Module 5: (8 hours)

Gas Insulated Substation: Evolution of GIS, Basics of GIS technology, Key design features, SF6 volume reduction, Reliability of GIS, Design tests, Gas tightness and monitoring, Global status of GIS. Gas Insulated Transmission Line: Why GIL, Historical development of GIL, Applications of GIL, Basic units of GIL, Basic insulation level and current carrying capacity of GIL, Gas mixture as insulation, Installation of GIL, Comparison of GIL with cables and overhead lines.

References

1. Hermann Koch, "*Gas Insulated Substations*", Wiley, 2014.
2. R.D. Begamudre, “*EHV AC transmission engineering*”, New age international, 2006.
3. Kimbark E.W., “*HVDC transmission*”, Wiley, 1965.
4. Arrilaga J, “*High voltage Direct Current Transmission*”, Peter Peregrinus, London, 2007

EE6592D MINI PROJECT

Pre requisites: Nil

L	T	P	C
0	0	2	1

Total hours: 26

Course outcomes:

CO1: Enable the engineering post graduate student to undertake individual mini research projects in the area of high voltage engineering under the guidance of a faculty member.

CO2: Develop a complete design and do the hardware implementation.

CO3: Impart skills in preparing a detailed design report describing the relevance of the project, modelling aspects, methodologies and analysis of the results.

CO4: Effectively communicate by making an oral presentation before an evaluation committee

The mini project can be analytical / simulation/design or/and fabrication in any of the areas in high voltage engineering. Project must be done by individual student. A faculty coordinator will coordinate the project work of all students. The mini project is usually allotted by the Department at the beginning of 2nd semester and preferably shall be completed before the end of 2nd semester.

The project work is evaluated by a committee consisting of the concerned guide and two/three faculty members in the concerned area of the project. The faculty coordinator of the project will be a member of the evaluation committee of all the projects. The mode of presentation, submission of the report, method of evaluation, award of grades etc will be decided by the evaluation committee. Students shall submit both soft and hard copies (required number of copies) of project report in the prescribed form to the department and library after incorporating all the corrections and changes suggested by the evaluation committee.

EE7591D PROJECT–PART 1

Pre-requisites: Nil

L	T	P	C
0	0	20	10

Total hours: 260

Course Outcomes:

CO1: Pursue their interest in high voltage engineering through design, research, theoretical and experimental approach.

CO2: Identify a topic of interest and demonstrate the ability to carry out literature survey and select unresolved problems in the domain of the selected project topic.

CO3: Gain the expertise to use new tools and techniques for development of cost-effective and environment friendly designs.

CO4: Effectively communicate by making an oral presentation of the progress of work before an evaluation committee and develop the ability to write good technical report.

Main Project will be done by the individual students normally in two semesters. Students are exposed to various topics in high voltage engineering and allied areas and the recent developments through the class seminars so as to inculcate interest in these topics. Faculty members propose projects /broad area of work and student will be asked to meet the faculty member who is offering the project of interest for guidance. Student can also select the topic for the interdisciplinary project after discussions with guide. Students can carry out their projects in R&D organizations/ industries which have facility in the proposed area with an officer from there as external guide and with an internal guide from Department.

Students are required to undertake detailed technical work in the chosen area using one or more of the following: (i) Analytical models (ii) Computer simulations (iii) Hardware implementation. The assessment of the project will be done at the end of the semester by a committee consisting of three or four faculty members specialized in various fields of Electrical Engineering. The students will present their project work before the committee. The complete project report is not expected at the end of this semester. However, a 30-40 page typed report based on the work done will have to be submitted by the students to the assessing committee. The Department level evaluation shall have 50% weight in the final grading- 50% weight will be given to the assessment by the individual guide. Marks will be reported based on 100 as maximum. Result shall be finalized at the Department level.

EE7592D PROJECT –PART 2

Pre-requisites: EE7591D PROJECT –PART 1

L	T	P	C
0	0	28	14

Total hours: 364

Course Outcomes:

CO1: Develop comprehensive solution to issues identified in previous semester work and to meet the requirements as stated in project proposal.

CO2: Inculcate the ability to synthesize the results of the detailed analytical studies conducted, lay down validity and design criteria, interpret the results for application to the practical problems in the field of high voltage engineering.

CO3: Report the concept and detailed design solution and to effectively communicate the research contributions and publish in reputed journals/conference.

EE7592D PROJECT–PART 2is a continuation of EE7591D PROJECT –PART 1in the third semester. Students should complete the work planned in the third semester, attaining all the objectives, and should prepare the project report of the complete work done in the two semesters. They are expected to communicate their research contributions in reputed conferences and/or journals. The project evaluation committee of the M. Tech programme shall assess the project work during the fourth semester in two stages. Two internal evaluations shall be conducted in the department level followed by final viva-voce examination by the committee including an external examiner. The mode of presentation, submission of the report, method of evaluation, award of grades etc will be decided by the project evaluation committee. The students shall submit both soft and hard copies (required number of copies) of project report in the prescribed format to the department and library after incorporating all the corrections and changes suggested by the project evaluation committee.

EE 6521D HVDC TRANSMISSION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Identify significance of DC over AC transmission system, types and application of HVDC links in practical power systems.

CO2: Analyze different converters viz.3, 6 and 12 pulse converters.

CO3: Analyze AC/DC system interactions and know the operation and control of various MTDC systems.

CO4: Model AC/DC system and apply protection for HVDC system against transient overvoltage and over currents

Module 1: (10 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: (10 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: (10 hours)

Introduction – System simulation: Philosophy and tools – HVDC system simulation –Modeling ofHVDC 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*, 1stEd, Wiley,1965.
2. Arrillaga J., *“High Voltage Direct Current Transmission*”, Peter Peregrinus, 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.

EE6522D HIGH VOLTAGE POWER TRANSFORMERS AND CIRCUIT BREAKERS

Prerequisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Acquire knowledge about the build-up, modeling, and protection system of power transformers.
CO2: Accomplish insight regarding detailed power transformer features as loss phenomena, stray fields, impedance characteristics, insulation design etc.
CO3: Assess the condition of the transformer by performing various tests.
CO4: Acquire knowledge about the different types of circuit breakers for protecting power system equipment.
CO5: Understand the testing of circuit breakers

Module 1: (8 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. Sweep frequency response of power transformer.
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 Polymerization and Furan Analysis, Time domain and frequency domain dielectric response method.Impulse testing ofpower transformer for winding of low inductance

Module 4: (10 hours)

Introduction to HV switching devices, electric arcs, short circuit currents, TRV, CB types, air, oil and SF_6 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. Sivaji Chakravorti, DebangshuDey, Biswendu Chatterjee, "*Recent trends in the condition monitoring of transformers, Theory, Implementation and Analysis*", Springer Verlag London 2013.
3. Bernard Hochart, *Power Transformer Handbook*, Butterworth, 1987.
4. *The J & P Transformer Book*, 12th edition, M J Heathcote, Newnes, 1998.
5. *Transformers*, Bharat Heavy Electricals Limited, Tata McGraw Hill, 2001.
6. Blume, L.F., and BoyaJian, *Transformer Engineering*, John Wiley and Sons, 1951.
7. Garzon, R.D., *HV Circuit Breakers – Design and Applications*, Marcel and Dekker NY, 1996.
8. Flurscheim, C.H., *Power Circuit Breaker: Theory and Design*, Peter Peregrinus Ltd., 1975.
9. Ryan, H.M., and Jones G.R., *SF_6 Circuit Breaker*, Peter Peregrinus Ltd., 1989.

EE6523D CONDITION MONITORING OF POWER EQUIPMENT

Prerequisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: Understand various condition monitoring methods for power equipment

CO2: Assess the condition of transformers in operation using various electrical and non-electrical methods

CO3: Assess the condition of cables using various techniques such as partial discharge measurement

CO4: Assess the condition of GIS using various techniques

Module 1: (8 hours)

Dielectric Response Measurement: Polarization Mechanisms in Dielectrics.
Dielectric Response in Time-Domain. Polarization and Depolarization Current (PDC) Measurement, its test set up and typical results. Recovery Voltage Measurement (RVM) fundamentals, RVM Spectrum, typical RVM results.
Dielectric Response in Frequency-Domain. Frequency Domain Spectroscopy (FDS), FDS equipment and analysis. FRA.

Module 2: (12 hours)

Condition monitoring of transformers: Chemical and electrical methods
Traditional Condition Assessment Techniques for Oil-Paper Composite Insulation: Dissolved Gas Analysis (DGA), Furan Analysis, Degree of Polymerization (DP).
Moisture in Oil-Paper Composite Insulation: Moisture Distribution, moisture Dynamics, effects of moisture, moisture detection – Crackle Test, Karl Fischer Titration (KFT), equilibrium curves, comparison of equilibrium curves, ABB and Serena's Equations, moisture content in paper, moisture management, oil reclamation.
Assessing the condition of transformers using FDS, PDC and RVM methods.

Module 3: (9 hours)

Condition monitoring of cables:
Detection and localization of defects in cables by Partial discharge analysis, impedance spectroscopy, acoustic and UHF sensors and time domain reflectometry (TDR)

Module 4: (10 hours)

Condition monitoring of GIS:
Analysis of SF_6 samples from GIS, Gas density monitoring- online condition monitoring of GIS gas tightness and SF_6 leakages, Partial discharge monitoring- Online insight in the condition of the dielectric strength of the GIS installation.

References:

1. Sivaji Chakravorti, Debangshu Dey, Biswendu Chatterjee, "*Recent trends in the condition monitoring of transformers, Theory, Implementation and Analysis*", Springer Verlag London 2013.
2. R. E. James and Q. Su., "*Condition Assessment of High Voltage Insulation in Power System Equipment*", IET Power and Energy Series, 2008.
3. Hermann Koch, "*Gas Insulated Substations*", IEEE Press and John Wiley & Sons Ltd., 2014.

E6524D ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: Define EMI Environment, Coupling principles, Different sources of EMI and Mitigation Techniques.

CO2: Distinguish Measurement Techniques for Conducted Interference and the effect of power supply components on Conducted Emissions.

CO3: Describe the Grounding, Cabling, Shielding, Bonding mechanisms for EMC.

CO4: Describe various EMI filters and the EMI/EMC Standards.

Module 1: (8 hours)

BASIC CONCEPTS Definition of EMI and EMC with examples, Classification of EMI/EMC - CE, RE, CS, RS, Units of Parameters.

Module 2: (10 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 technique open area site, shielded anechoic chamber, TEM cell.EMI CONTROL METHODS AND FIXES Shielding, Grounding, Bonding, Filtering, EMI gasket, Isolation transformer, opto isolator.

Module 3: (10 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 ISSUES IN HIGH VOLTAGE ENGINEERING, Sources of EMI, EMI coupling modes - CM and DM, ESD Phenomena and effects, Transient phenomena and suppression, High frequency EMI sources, High Power EMI sources, EMC of High Voltage Equipments.

References:

1. Keiser, '*Principles of Electromagnetic*' , 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

EE6525D PULSED POWER ENGINEERING

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Understand the various circuits for generating pulsed power and the energy storage devices for the same

CO2: Understand the wave shape after travelling through transmission lines.

CO3: Understand the various insulating systems applicable to pulsed power systems.

CO4: Design circuits for various applications of pulsed power.

Module 1: (10 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: (10 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)

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: (10 hours)

Applications: High Power Microwaves, mass drivers, pollution control, food processing, 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 ., '*J. C. Martin on Pulsed Power',* Plenum Press, 1996.
3. G.A. Mesyats, '*Pulsed Power'*, Kluwer Academics/Plenum 2005.

EE6526D HIGH VOLTAGE TESTING TECHNIQUES

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: Understand the requirement of high voltage testing on various power system equipment

CO2: Understand the various tests to be conducted on various power system equipment

CO3: Be able to interpret the test result and identify type of defect

CO4: Be able to design a high voltage laboratory with fencing, earthing and shielding.

Module 1: (13 hours)

Objectives of high voltage testing - classification of testing methods- self restoration and non-self restoration systems- indoor and outdoor insulations-standards and specifications - measurement techniques - Diagnostic testing - online measurement, influences and correction of ambient conditions - Artificial Pollution tests- salt-fog method, solid layer method -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 2: (9 hours)

Testing of insulators, bushings, surge arresters: various type tests, sample tests, routine tests to be conducted on insulators, bushings and surge arresters.

Module 3: (9 hours)

Testing of power transformers – testing methodology - recording of oscillograms - interpretation of test results.

Module 4: (8 hours)

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.
6. Nelson W., "*Applied Life Data Analysis*", John Wiley and Sons, New York, 1982.
7. 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.
8. IEC – 60270, "*HV Test technique – Partial Discharge Mechanism*", 3rd Edition, December 2000.

EE6101D SYSTEMS THEORY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Integrate the concepts of linear algebra to be applied in systems theory
CO2: Explain the various tools used for the analysis of both LTI and LTV systems
CO3: Apply various techniques for the analysis of system stability
CO4: Analyze and categorize systems with respect to various properties

Module 1: (8 hours)

Basics of linear algebra - Vector spaces, dimension, basis, subspaces, dual spaces, annihilators, direct sum, linear transformations, matrix representations, similarity, rank and nullity.

Module 2: (9 hours)

Linear Systems –State space models, explicit solutions to linear differential equations, solution to LTI and LTV systems, Solutions to homogeneous and non homogeneous cases, Computation of matrix exponentials using Laplace transforms and Jordan Normal form, positive definite matrices, quadratic forms.

Module 3: (10 hours)

Minimal realizations and co-prime fractions, canonical lforms,Markovparameters,Hankelmatrices
Stability - Internal or Lyapunov stability, Lyapunov stability theorem, Eigen value conditions for Lyapunovstability,Input -Output stability: BIBOstability, Time domain conditions for BIBO stability. Frequency domain conditions for BIBOstability. BIBO versus Lyapunov stability

Module 4: (12 hours)

Controllability and Observability - Controllable and reachable subspaces, Physical examples and system interconnections, Reachability and controllability Gramians, Controllabilty matrix(LTI), Eigen vector test for controllability, Lyapunov test for controllability, Controllable decomposition and block diagram interpretation, Stabilizable system, Eigen vector test for stabilizability, Popov-Belevitch_Hautus (PBH) Test for stabilizability, Lyapunov test for stabilizability. Feedback stabilization based on Lyapunov test, Unobservable and unconstructable subspaces, Physical examples, observability and Constructability Gramians, Gramian based reconstruction, Duality (LTI), Observable decompositions, Kalman decomposition theorem, Detectability, detectability tests, State estimation, Eigen value assignment by output injection, Stabilization through output feedback

References:

1. Chi-Tsong Chen, *‘Linear System Theory and Design’,* Oxford University Press,1984
2. John S. Bay, *‘Fundamentals of Linear State Space Systems’,* Mc-Graw Hill, 1999
3. Thomas Kailath, *‘Linear System’,* Prentice Hall, 1990
4. Gillette, *‘Computer Oriented Operation Research’*, Mc-Graw Hill Publications.
5. K. Hoffman and R. Kunze, *‘Linear Algebra’*, Prentice-Hall (India), 1986.
6. F.M. Callier and C.A. Desoer, *‘Linear System Theory’*, Springer Verlag, 1991
7. P. Halmos, *‘Finite Dimensional Vector Spaces’*, Springer,

EE6103D MEASUREMENTS AND INSTRUMENTATION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Recognize about general units errors and significant digits in measurements.
CO2: Discuss about analog instruments and null balance methods for measurements.
CO3: Discuss digital measurement techniques.
CO4: Outline the applications of Data Acquisition Systems and virtual instrumentation.

Module 1: (8 hours) Units, significant digits and errors in measurements

C.G.S electrostatic and electromagnetic systems of units- Practical and legal units and their relationship to the absolute units- Dimensions of electrical quantities- The M.K.S. system of units- International and absolute units and standards, significant digits.
Measurement and Error-Accuracy and precision- Types of errors- Systematic and random errors, propagation of errors.

Module 2: (13 hours) Analog instruments and null balance methods for measurements

Analog Indicating instruments- Moving iron instruments- Moving coil instruments- Permanent magnet and dynamometer type instruments- electrostatic instruments- thermal instruments- induction instruments-rectifier instruments
Null balance methods of measurement-potentiometer Principles-Bridge configuration-AC Bridges-Classification of AC bridge circuits- DC bridge analysis- Extension of instrument range-current transformer theory- voltage transformers.

Module 3: (11 hours) Digital Measurement techniques

Digital Measurement techniques- counters and timers. Time measurement- phase measurement-capacitance measurement- frequency measurement- ratio of two frequencies- high frequency- low frequency- peak frequency-Voltage measurement using digital techniques- ADC's Digital Multimeter.
Graphical measurement techniques- CRO-DSO

Module 4: (7 hours) Data acquisition systems and virtual instrumentation

Analog and digital data acquisition systems-Virtual instrumentation- concepts- virtual versus real instrumentation - physical quantities and analog interfaces, hardware and software- user interfaces-applications of virtual instrumentation.

References:

1. A.D. Helfrick, W.D. Cooper,'*Modern Electronic Instrumentation and Measurement Techniques'*, Prentice-Hall of India pvt ltd, 1994.
2. Golding and Widdis, *'Electrical measurements and measuring instruments'*,Reem publications, Newdelhi, 5thEdn, 2009
3. Ernest Frank,*'Electrical measurement analysis'*, Tata McGraw-hill publishing company ltd, Bombay,1959
4. G.W. Johnson, *'LabVIEW graphical programming practical application in Instrumentation and Control'*, McGraw Hill, New York, 1997.

EE6104D ADVANCED INSTRUMENTATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Summarize about the fundamental concepts of measurement systems.
CO2: Recognise the static and dynamic characteristics of measuring instruments.
CO3: Review the mathematical modelling and time response of first order and second order measurement systems.
CO4: Study and analysis of amplitude modulation of measurements and the design consideration of such amplitude modulated measurement systems.
CO5: Discuss the response of measurement systems to random inputs.
CO6: Outline the requirements to ensure accurate measurements

Module 1: (9 hours) Generalized measuring system

Generalized input output configuration of measuring system. Different methods of correction, General principles.Methods of inherent sensitivity, principle of filtering, method of opposing inputs.

Module 2: (10 hours) Static and dynamic characteristics of measurement system

Static characteristics of measurement system. Computer aided calibration and measurement. Concept of development of software.Dynamic characteristics.Mathematical Models.General concepts of transfer functions (with special reference to measuring system). Classification of instruments based on their order and their dynamic response and frequency response studies.

Module 3: (10 hours) Time domain analysis
Time Response of general form of first order and second order measurement systems to various input (a) periodic (b) transient. Characteristics of random signals.Measurement system response to random inputs.

Module 4: (10 hours) Signal Processing and Conditioning

Study and analysis of amplitude modulation of measurements and design consideration of such amplitudes modulated measurement systems. Requirements on instrument transfer function to ensure accurate measurements.

References:

1. Ernest O. Doebelin,*'Measurement system Application and Design'*, McGraw Hill International Editions, 1990
2. K. B. Klaasen, *'Electronic Measurement and Instrumentation'*, Cambridge University Press, 1996.
3. Bernard Oliver, John Cage, '*Electronic Measurements and Instrumentation'*, Tata McGraw-Hill Edition, 2008
4. A.D. Helfrick, W.D. Cooper,'Modern Electronic Instrumentation and Measurement Techniques', Prentice-Hall of India pvt ltd, 1994

EE6105D DIGITAL CONTROL: THEORY AND DESIGN

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain the advanced topics of statistics and stochastic processes
CO1: Explain the stochastic modelling of uncertain signals and dynamical systems
CO3: Apply stochastic modelling for control system analysis and design
CO4: Choose suitable methods for control system identification
CO5: Develop algorithms for analytical modelling & optimal control

Module 1: (9 hours) Introduction to digital control

Introduction -Discrete time system representation –Sample & Hold-Mathematical modeling of sampling process – Data reconstruction-Design of the hardware and software architecture - Software requirements- Selection of ADC and DAC- Choice of the sampling period –Prefilter/Antialiasing filters - Effects of quantization errors - Phase delay introduced by the ZOH-Sampling period switching- Dual-rate control
Modeling discrete-time systems by pulse transfer function -Revisiting Z-transform -Mapping of s-plane to z-plane -Pulse transfer function - Pulse transfer function of closed loop system - Sampled signal flow graph -Stability analysis of discrete time systems -Jury stability test - Stability analysis using bi-linear transformation

Module 2: (10 hours) Design of sampled data control systems

Design of PID controller-Filtering the derivative action- Integrator windup- Bumpless transfer between manual and automatic mode - Incremental form-Root locus method - Controller design using root locus - Root locus based controller design using MATLAB - Nyquist stability criteria - Bode plot - Lead compensator design using Bode plot - Lag compensator design using Bode plot - Lag-lead compensator design in frequency domain-Deadbeat response design -Design of digital control systems with deadbeat response - Practical issues with deadbeat response design - Sampled data control systems with deadbeat response

Module 3: (9 hours) Discrete state space model and state feedback design

Introduction to state variable model for SISO systems- Various canonical forms - Characteristic equation, state transition matrix - Solution to discrete state equation-Controllability, observability and stability of discrete state space models -Controllability and observability - Stability
Pole placement by state feedback - Set point tracking controller - Full order observer - Reduced order observer-Servo Design- State feedback with Integral Control-Deadbeat Control by state feedback and deadbeat observers -Output feedback design - Output feedback design: Theory - Output feedback design:Examples. Introduction to Multivariable & Multi-input Multi-output (MIMO) Digital Control Systems

Module 4: (11 hours) Nonlinear Digital control systems

Discretization of nonlinear systems - Extended linearization by input redefinition - - input and state redefinition - output differentiation - Extended linearization using matching conditions - Nonlinear difference equations - Logarithmic transformation- Equilibrium of nonlinear discrete-time systems - Lyapunov stability theory- Lyapunov functions - Stability theorems -Rate of convergence - Lyapunov stability of linear systems - Lyapunov's linearization method- Instability theorems - Estimation of the domain of attraction - Stability of analog systems with digital control-Hybrid Systems - State plane analysis - Discrete-time nonlinear controller design- Controller design using extended linearization-Controller design based on Lyapunov stability theory - Input-output stability and the small gain theorem-Absolute stability

References:

1. B.C Kuo , Digital Control Systems (second Edition),Oxford University Press, Inc., New York, 1992
2. G.F. Franklin, J.D. Powell, and M.L. Workman, Digital control of Dynamic Systems, Addison-Wesley Longman, Inc., Menlo Park, CA , 1998.
3. M. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill Publishing Company, Third Edition, 2009.
4. John F. Walkerly, Microcomputer architecture and Programs, John Wiley and Sons Inc., New York, 1981.
5. K. Ogata, Discrete Time Control Systems, Addison-Wesley Longman Pte. Ltd., Indian Branch ,Delhi, 1995.
6. C. H. Houpis and G.B. Lamont, Digital Control Systems, McGraw Hill Book Company, 1985.
7. C.L.Philips and H.T Nagle,Jr., Digital Control System Analysis and Design, Prentice Hall, Inc., Englewood Cliffs,N.J.,1984
8. M. Sami Fadali Antonio Visioli,Digital Control Engineering Analysis and Design, Academic Press,225 Wyman Street, Waltham, MA 02451, USA,Second Edition

EE6121D DATA ACQUISITION AND SIGNAL CONDITIONING

Pre-requisite:Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain characteristics of transducers and various signal conditioning techniques.
CO2: Design filters for signal conditioning.
CO3: Explain signal conversion (analog to digital and digital to analog) as well as transmission techniques
CO4: Describe various interfacing techniques and standards for communication between instruments

Module 1: Transducers & Signal Conditioning(10 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 , Opto-sensors, 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. Op-amp 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(9 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

EE6122D BIOMEDICAL INSTRUMENTATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Course outcomes

CO1: State and recognize the practical problems faced in objective analyses of biomedical signals.
CO2: Describe and interpret the various mathematical techniques involved in biomedical signal processing
CO3: Illustrate and examine the characteristics of signals like EEG and apply the signal processing techniques to obtain the medically significant information from the signals concerned.
CO4: Analyze and infer the entities associated with bio-signals.
CO5: Evaluate and conclude the medically significant information obtained from the task of biomedical signal processing.

Module1: (10 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 – pulseoximeter –skin reflectance oximeter -measurement on pulmonary system – spirometry – pulmonary function analyzers –ventilators

Module 3: (9 hours)

Lasers in medicine – Argon laser – Carbon dioxide laser -laser safety –X ray applications –X-ray machine– dental X-ray machine – ultrasound in medicine –electro therapy – hemodialysis –artificial kidney –dialyzers –membranes for hemodialysis.

Module 4: (10 hours)

Measurement of pH, pCO2, pO2 - radiotherapy– audiometry - electrical safety in hospitals.
Introduction to Biomedical signals, Characteristics of bio medical signals, bio signal acquisition, Artifacts, Fourier transform and Time-frequency analysis of biomedical signals.

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"*, Prentice Hall, 1981
5. John Enderle, *"Introduction to Biomedical Engineering"*, Academic Press, 2005
6. Joseph D Bronzino, *"Biomedical engineering hand book"*, CRC Press, 2000
7. MetinAkay (editor), *"Wiley encyclopedia of biomedical Engineering*", Wiley, 2003
8. E.N.Bruce, *"Biomedical Signal Processing & Signal Modeling*", Wiley, 2001
9. L.Sörnmo, P Laguna, *"Bioelectrical Signal Processing in Cardiac & Neurological Applications",* Elsevier, 2005.
10. R.M.Rangayyan, *"Biomedical Signal Analysis:A case study approach*", IEEE Press and Wiley 2002.
11. Semmlow, Marcel Dekker*, "Biosignal and Biomedical Image Processing*", 2004

12. Enderle, *"Introduction to Biomedical Engineering"*, 2/e, Elsevier, 2005
13. D.C.Reddy , *"Biomedical Signal Processing: Principles and techniques*", Tata McGraw Hill, New Delhi, 2005
14. A. Cohen, *"Biomedical Signal Processing",* Vol. I and II, CRC, Boca Raton, FL, 1986
15. W. J. Tompkins (Editor), "*Biomedical Digital Signal Processing*", Prentice Hall, 1995
16. S. R. Devasahayam, "*Signals and Systems in Biomedical Engineering: Signal Processing and Physiological Systems Modeling"*, Kluwer Academic/ Plenum, New York, NY, 2000

EE6140D ADVANCED SOFT COMPUTING TECHNIQUES

Pre-requisite**:**Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Construct intelligent systems and control using Artificial neural network
CO2: Integrate theoretic foundations of Fuzzy Logic Systems to be used in engineering applications.
CO3: Describe the concepts of genetic algorithms
CO4: Apply the knowledge of Soft Computing Techniques in engineering problems
CO5: Simulate intelligent control systems to evaluate the performance

Module 1: (9 hours)

Introduction Neural Networks, Biological Neuron, Biological and Artificial Neuron Models, types of Neuron Activation function, ANN Architectures, supervised, and unsupervised learning, Perceptron Models, training Algorithms, Limitations of the Perceptron Model and Applications, Computer based simulation

Module 2: (11 hours)

Multilayer Feed forward Neural Networks - Back propagation Algorithm, Limitations of Back propagation Algorithm, Radial Basis Function network structure - covers theorem and the separability of patterns - RBF learning strategies, Applications in forecasting and pattern recognition and other engineering problems, Computer based simulation

Module 3: (11 hours)

Introduction to classical sets - properties, Operations and relations; Fuzzy sets, Membership, Uncertainty, Operations, properties, fuzzy relations, cardinalities, membership functions., Fuzzification, Membership value assignment, development of rule base and decision making system, Defuzzification to crisp sets, Defuzzification methods - Mamdani Fuzzy Models, Sugeno Fuzzy Models - engineering applications

Module 4: (8 hours)

Introduction to Optimization, types of optimization problem, optimization algorithms, classification, History of evolutionary, Advantages of evolutionary computation, Introduction to genetic algorithms, The genetic computation process-natural evolution-parent selection-crossover-mutation-properties - classification - Application to engineering problems, Computer simulation practices.

References:

1. B.Yegnanarayana, *“Artificial Neural Networks,”* PHI, India, 2006.
2. Limin Fu, *“Neural Networks in Computer Intelligence,”* McGraw Hill, 2003.
3. N. Yadaiah and S. Bapi Raju, *“Neural and Fuzzy Systems: Foundation, Architectures and Applications,”* Pearson Education
4. Goldberg D.E., *"Genetic Algorithms in Search Optimization and Machine Learning",* Addison Wesley,1989

EE6201D COMPUTER METHODS IN POWER SYSTEM ANALYSIS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Formulate network admittance and impedance matrix for various analyses of power systems.
CO2: Execute load flow and short circuit analysis on large scale AC, DC and AC-DC power systems using digital techniques.
CO3: Conduct optimal scheduling and unit commitment of generators.
CO4: Execute state estimation and contingency analysis on large scale power systems using digital techniques.

Module 1: (10 hours)

Network modelling - System Graph. Loop, Cutest and Incidence Matrices - Y Bus Formation – Mutually coupled branches in Y Bus - solution techniques for linear networks -Guassian Elimination, LU Factorization, Network reduction techniques - Sparsity programming and Optimal Ordering - [ZBUS] Building Algorithm with Mutually coupled branches - digital simulation.

Module 2: (10 hours)

Power Flow Analysis: Newton-Raphson Method. Decoupled and Fast Decoupled Methods, DC Power Flow, AC-DC Load Flow Analysis, Load Flow under Power Electronic Control

Fault Analysis: Sequence Matrices. Symmetrical and Unsymmetrical Short-Circuit Analysis of Large Power Systems - Phase Shift in Sequence Quantities Due To Transformers - digital simulation

Module 3: (9 hours)

Power System Optimization - Unit Commitment - Priority List and Dynamic Programming Methods - Optimal Load Flow Solution - Optimal scheduling of Hydrothermal System - Optimum Reactive Power Dispatch and control, Economic scheduling in deregulated environment - AI Applications - digital simulation

Module 4: (10 hours)

Power System Security, Factors Affecting Security.State Transition Diagram. Contingency Analysis Using Network Sensitivity Method And AC Power Flow Method, Z bus method, Correcting The Generation Dispatch Using Sensitivity Methods, State Estimation, Bad data detection, State estimation with phasor measurements.- digital simulation

References:

1. John J. Grainger and William D. Stevenson, *Power System Analysis*, Tata McGraw-Hill, 2003
2. Haadi A. Sadat, *Power System Analysis*, McGraw Hill Co. Ltd., India, 2000.
3. I.J. Nagarath, D.P. Kothari, *Power System Engineering*, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 1994.
4. George L. Kusic, *Computer Aided Power System Analysis*, Prentice Hall of India (P) Ltd., New Delhi, 1989.
5. A.J. Wood, B.F. Wollenberg, *Power Generation, Operation and Control*, John Wiley & Sons, New York, 1984.
6. J. Arrilaga, C.P. Arnold, B.J. Harker, *Computer modelling of Electric Power Systems,* Wiley, New York, 1983.
7. A.K. Mahaianabis, D.P. Kothari, S.I. Ahson, *Computer Aided Power System Analysis & Control,* Tata McGraw Hill, New Delhi, 1988.

8. O.I. Elgard, *Electric Energy System Theory: An Introduction*, 2nd ed., McGraw Hill, New York, 1982.
9. Mariesa L. Crow, *Computational Methods for Electric Power Systems*, CRC Press, 2010.
10. T. J. E. Miller, *Reactive power control in Electrical system*, John Wiley & Sons, New York, 1982.
11. Arthur R. Bergen, Vijay Vittal, *Power Systems Analysis*, Pearson Education, 2009.

EE6202D POWER SYSTEM DYNAMICS AND CONTROL

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Design and analyze Automatic Generation control (AGC) and AVR for power systems considering economic dispatch.
CO2: Model and analyze dynamical systems to address various power system stability problems.
CO3: Execute digital simulation of large power system for small signal and transient stability analyses and develop stability enhancement methods.
CO4: Model and analyze voltage stability problem based on static and dynamic approach and develop stability enhancement methods.

Module 1: (10 hours)

Generation Control Loops. AVR Loop.Performance and Response.Automatic Generation Control of Single Area and Multi Area Systems. Static and Dynamic Response of AGC Loops – analysis using digital simulation - Economic Dispatch and AGC, AGC in a Deregulated Environment, Recent advances in AGC

Module 2: (10 hours)

Small signal angle instability (low frequency oscillations) - Power System Model for Low Frequency Oscillation Studies, damping and synchronizing torque analysis, Eigen value Analysis, Improvement of System Damping with Supplementary Excitation Control, Standard models for PSS representation-supplementary modulation control of FACTS devices, sub-synchronous frequency oscillations - Sub Synchronous Resonance and Countermeasures, IEEE Benchmark models for SSR studies

Module 3: (10 hours)

Transient Stability Problem, Modeling of Synchronous Machine, Loads, Network, Excitation Systems, Turbine And Governing Systems, Trapezoidal Rule of Numerical Integration Technique For Transient Stability Analysis, Simultaneous Implicit Approach for Transient Stability Analysis of Multi-machine Systems, Data For Transient Stability Studies, analysis using digital simulation - Transient Stability Enhancement Methods

Module 4: (9 hours)

Voltage Stability Problem.Real and Reactive Power Flow in Long Transmission Lines.Effect of ULTC and Load Characteristics on Voltage Stability. Voltage Stability Limit. Voltage Stability Assessment Using PV Curves. System Modelling-Static and Dynamic Analysis-Voltage Collapse Proximity Indices.Voltage Stability Improvement Methods.

References:

1. P. M. Anderson, A. A. Fouad, *Power system control and stability*, 2nd ed. John Wiley & Sons, 2008
2. P. Kundur, *Power System Stability and Control*, McGraw Hill, New York, 1994.
3. A.J. Wood, B.F. Wollenberg, *Power Generation, Operation And Control*, 2nd ed., John Wiley And Sons, New York, 1996.
4. O.I. Elgard*, ElectricEnergy System Theory: An Introduction*, 2nd ed., McGraw Hill, New York, 1982
5. K.R. Padiyar, *Power System Dynamics, Stability And Control*, Interline Publishing (P) Ltd., Bangalore, 1999
6. M A Pai, D P Sen Gupta, K R Padiyar, *Small Signal Analysis of Power Systems*, Narosa Series in Power and Energy Systems, 2004
7. Leonard L Grigsby, *Power Systems*, Electrical Power Engineering Handbook, CRC Press, New York, 2007.

8. C. Van Custem, T. Vournas, *Voltage Stability Of Electric Power Systems*, Rlever Academic Press
9. Yao-Nan-Yu, *Electric Power System Dynamics,* Academic Press, 1983
10. J. Arrilaga, C.P. Arnold, B.J. Harker, *Computer Modeling of Electrical Power Systems*, Wiley, New York, 1983.
11. I.J. Nagrath, O.P. Kothari, *Power System Engineering*, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 1994.

EE6203D DISTRIBUTED GENERATION & MICROGRID

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Analyze the concept of distributed generation and technologies
CO2: Investigate the technical challenges of Distributed Generation technologies
CO3: Design the microgrid architectures and its control operation
CO4: Explore smartgrid technologies and infrastructure

Module 1: (10 hours)

Modern Power System: Generation - Transmission - Distribution - Loads - Introduction to Distributed Generation (DG) - Technologies of DG - IEEE 1547- Solar photovoltaic generation - wind energy - Wind power plants - Microturbines - Fuel Cell - Storage Systems - batteries, fly-wheels, ultracapacitors - unit sizing of DGs - Case studies

Module 2: (10 hours)

Penetration of DGs Units in Power Systems - Integration of DGs Units in Distribution Network -Modern Power Electronics for DGs Applications – multiple and single input dc-dc converters - ac-dc and dc-ac converters - Technical restrictions - Protection of DGs - Economics of DGs –Pricing and Financing framework for DG units - Optimal placement of DGs - Case studies

Module 3: (10 hours)

Introduction to Microgrids - AC and DC microgrids - Operational Framework of Microgrids - anti-islanding schemes - Distribution Management System (DMS) - Microgrid System Central Controller (MGCC) - Local Controllers (LC) - Economic, environmental and operational benefits of Microgrids in a distribution network - Demand Response Management in Microgrids - Business Models and Pricing Mechanism in Microgrids - Interconnection of Microgrids

Module 4: (9 hours)

Introduction to Smart Grids (SG) - Factors affecting the growth of SG - The global reality in the field of smart grids and transition into future grids - Smart Agents - Electronics and communications infrastructure in SG - ICT Technologies - smart meters - metering infrastructures - metering equipment - communication of metering equipment - communication protocols - Metering Data Management Systems (MDMS) - Application of SGs - Interconnections issues between SGs

References:

1. N. Hatziargyriou, *Microgrids: Architectures and Control*, Wiley-IEEE Press, 1st Edition, 2014
2. J. N. Twidell&A. D. Weir, *Renewable Energy Sources*, University press ,Cambridge, 2001
3. James Larminie , Andrew Dicks , *Fuel Cell Systems,* John Weily& Sons Ltd, 2000
4. J. F. Manwell , J. G. McGowan, A. L. Rogers , *Wind Energy Explained*, John Weily& Sons Ltd 2009
5. Loi Lei Lai, Tze Fun Chan, *Distributed Generation- Induction and Permanent Magnet Generators*, IEEE Press, John Wiley & Sons, Ltd., England. 2007.
6. AmirnaserYezdani, and Reza Iravani, *Voltage Source Converters in Power Systems: Modeling, Control and Applications*, IEEE John Wiley Publications, 2009.

EE6204D FACTS AND CUSTOM POWER

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Analyze passive and active Reactive Power Compensation Schemes at Transmission and Distribution level in Power Systems.
CO2: Analyze operation and control of various FACTS devices.
CO3: Digital simulation and case study of various FACTS controllers.
CO4: Design and analyze Custom power devices for power quality improvement.

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 compensation at transmission and distribution level – Static versus passive VAr Compensators

Module 2: (10 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: GCSC, TSSC, TCSC, SSSC -Static voltage and phase angle regulators - TCVR and TCPAR - Operation and Control –Applications – Digital simulation and analysis - SSR and damping schemes

Module 3: (9 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 - Interline power flow controller – Transient stability improvement and power oscillation damping -Digital simulation and analysis.

Module 4: (10 hours)

Power quality problems in distribution systems – Custom power devices - mitigation of harmonics, passive filters, active filtering – shunt, series and hybrid filters and their control – Distribution STATCOM, Dynamic Voltage Restorer – Unified Power Quality Conditioner - Digital simulation and analysis- Custom Power Devices for Isolation, Protection and Reconfiguration-STS, SCL,SCB.

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 ed., 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, Newyork, 1982.
7. F.P. Beer and E.R. Johnston, *Vector Mechanics for Engineers – Statics*, McGraw Hill Book Company, 2000.

EE6206D DIGITAL PROTECTION OF POWER SYSTEMS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes

CO1: Explain various digital protective schemes for transmission lines and power apparatus.
CO2: Select and design instrument transformers for a specific protection scheme design.
CO3: Realise numerical relays in hardware platform.
CO4: Conduct testing and coordination of relays.

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: (13 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. Relay coordination- Relay setting calculations. Primary and backup protection, application and philosophy with applied relay engineering examples

Module 3: (11 hours)

Digital Protection of power system apparatus – protection of generators – Transformer protection – magnetizing inrush current – Application and connection of transformer differential relays – transformer over current protection. Bus bar protection - line protection - distance protection–long EHV line protection - Power line carrier protection Motors protection; Pilot wire and Carrier Current Schemes; Reactor protection – Protection of boosters - capacitors in an interconnected power system. System grounding –ground faults and protection; Load shedding and frequency relaying; Out of step relaying; Re-closing and synchronizing.

Module 4: (7 hours)

Integrated and multifunction protection schemes -SCADA based protection systems- Fault Tree Analysis; Testing of Relays- Field test procedures for protective relays.
Adaptive relaying-AI & Fuzzy Based Protection, Intelligent Transmission Line Relaying Fault Detection

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
15. P M Anderson, *Power System Protection*, IEE Press, 2012
16. Edward Wilson Kimbark, *Power System Stability, Volume II: Power Circuit Breakers and Protective Relays,* Wiley-IEEE Press, March 1995.
17. IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems - Buff Book, IEEE Standard 242-198.

EE6221D POWER QUALITY ISSUES AND REMEDIAL MEASURES

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain various power quality issues, remedial measures and standards.
CO2: Develop models and analyse harmonics in networks and components
CO3: Design active power factor correction based on static VAR compensators and its control techniques
CO4: Analyze series and shunt active power filtering techniques for harmonic cancellation and isolation
CO5: Explain voltage quality improvement techniques and NEC grounding requirements and solutions to grounding and wiring problems

Module 1: (8 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: (11 hours)

Power factor improvement- Passive Compensation- Passive Filtering- Harmonic Resonance-Impedance Scan Analysis- Active Power Factor Corrected Single Phase Front End Converters, Control Methods for Single Phase APFC- Three Phase APFC and Control Techniques- PFC Based on boost conversion technique and Bilateral Single Phase and Three Phase Converters. Static VAR compensators- SVC and STATCOM.

Module 4: (10 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- series active power filtering techniques for harmonic cancellation and isolation. Uninterruptible Power Supplies- Constant Voltage Transformers - 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.
4. J. Arrillaga, B.C. Smith, N.R. Watson & A. R.Wood, *Power system Harmonic Analysis*, Wiley, 1997.
5. E Fuchs, M.A.S. Masoum, *Power Quality in Power Systems and Electrical Machines*, Elsevier Inc.,

2008.
6. A. Moreno, *Power Quality-Mitigation Technologies in a disturbed environment*, Springer, 2007.
7. W.E.Kazibwe, M.H.Sendaula, *Electric Power Quality Control Techniques*, Van Nostrand Reinhold, 1993.
8. IEEE Transaction and IET Journal papers

EE6222D WIDE AREA MONITORING & CONTROL OF POWER SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain SynchrophasorMeasurement Techniques
CO2: Implement and test wide area measurement systems
CO3: Realize optimal placement of PMU and state estimation using PMU data
CO4: Monitor, analyse and control power system conditions in real time

Module 1: (11 hours)

Phasor Measurement Techniques: Basic Concepts and Definitions SCADA vs PMU, Synchrophasors, Frequency, and ROCOF, Steady-State and Dynamic Conditions in Power Systems, Classical Phasor Versus Dynamic Phasor, Basic Definitions of Accuracy Indexes, Algorithms for Synchrophasors, Frequency, and ROCOF, Methods to Calculate Synchrophasors based on a Steady-State Model and Dynamic Signal Model, Evaluation of Frequency and ROCOF, Dynamic Behavior of Phasor Measurement Algorithms

Module 2: Phasor Measurement Units and Phasor Data Concentrators (10 hours)

Phasor measurement units and Phasor data concentrators: WAMS architecture, Sensors for PMUs, International Standards for Instrument Transformers, Accuracy of Instrument Transformers, Transducer Impact on PMU Accuracy, Hardware for PMU and PMU Integration, PMU Architecture, Data Acquisition System, Synchronization Sources, Communication and Data Collector, Distributed PMU, International Standards for PMU and Tests for Compliance, IEC 61850

Module 3: (10 hours)

State Estimation and PMUs: Formulation of the SE Problem, Network Observability-SE Measurement Model, SE Classification, State estimation with phasor measurents, Linear state estimation, Dynamic estimators.
Optimal PMU placement, meta-heuristic and deterministic algorithms, Integer Linear Programming Technique

Module 4: (10 hours)

WAMS applications- real-time analysis and technologies to detect, locate and characterize power system disturbances, monitoring power system oscillatory dynamics- Interpretation and visualization of wide-area PMU measurements, power system control with phasor feedback, discrete event control.

References:

1. Antonello Monti, Carlo Muscas, FerdinandaPonci, *Phasor Measurement Units and Wide Area Monitoring Systems*, Academic Press, 2016
2. A.G.Phadke, J.S. Thorp, *Synchronized Phasor Measurement and Their Applications*, Springer 2008
3. Yong Li, Dechang Yang, Fang Liu, Yijia Cao, Christian Rehtanz, *Interconnected Power Systems: Wide-Area Dynamic Monitoring and Control Applications*, Springer, 2015
4. Ali Abur, Antonio Gómez Expósito, *Power System State Estimation: Theory and Implementation*, CRC Press, 2004
5. Ma J., Makarov Y., Dong Z, *Phasor Measurement Unit and its Applications on Modern Power Systems*, Springer, 2010
6. IEEE Power & Energy Society, *IEEE Standard for Synchrophasor Data Transfer for Power Systems*, IEEE New York, 2011

7. Xu B, Abur A, *Optimal Placement of Phasor Measurement units for State Estimation*, PSERC, Final Project Report, 2005
8. P. M. Anderson, A. A. Fouad, *Power system control and stability*, 2nd ed. John Wiley & Sons, 2008
9. P. Kundur, *Power System Stability and Control,* McGraw Hill, New York, 1994.

EE6223D POWER SYSTEM PLANNING AND RELIABILITY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain basic reliability concepts and reliability measures.
CO2: Develop analytical models for power system reliability analysis.
CO3: Implement and use algorithms for power system reliability analysis
CO4: Design and build reliable power system.

Module 1: (9 hours)

System Planning: Objectives of system planning: Long term and short term planning-stages in planning –Policy studies -Planning standardization studies- System and Network Reinforcement studies
Load forecasting: Classification of loads-Forecast methodology- Energy forecasting-Non weather sensitive forecast-Weather sensitive forecast- Total forecast-Annual and monthly peak load forecasting

Module 2: (7 hours)

Generator System Models- State Load Model- Probability Methods- Unit Unavailability- Outage Probability. Generating Capacity Limits- Recursive Techniques- Capacity Expansion Analysis - Scheduled Outages - Reliability Indices

Module 3: (11 hours)

Reliability analysis of isolated and Interconnected Systems - Two Systems with Tie- Probability Array Methods- Reliability Indices- Variable Reserve and Maximum Peak Load Reserve- Multi Connected Systems. Distribution System- Interruption Indices- System Performance- risk prediction- Radial Systems- Effect of Load Transfer- Line Failures- Parallel and Mesh Networks- Industrial Systems.
Capacity state classification- Average –Interruption rate method – LOLP method

Module 4: (12 hours)

Introduction to system modes of failure – the loss of load approach – frequency & duration approach – spare value assessment – multiple bridge equivalents
Generation system cost analysis-Production costing –Fuel inventories-Energy transaction and off-peak loading
Transmission system Expansion Planning: Tellegen's theorem-Network sensitivity. Network Decision-Problem formulator solution using DC load flow. An overview of distribution system planning

References:

1. Sullivan, R.L., *Power System Planning*, Heber Hill, 1987.
2. Roy Billington, *Power System Reliability Evaluation*, Gordan& Breach Scain Publishers, 1990.
3. Endrenyi, J., *Reliability modelling in Electric Power System*, John Wiley, 1980.
4. Dong, Z., Zhang, P. Ma, J., Zhao, J., Ali, Meng, K., Yin, *Emerging Techniques in Power System Analysis*, Springer, 1st edition 2010.
5. S.C. Savulescu, *Real-Time Stability assessment in modern power system control centres*, John Wiley & Sons, January 2009
6. Bo Bergman, Jacques de Mare, Thomas Svensson, Sara Loren, *Robust Design methodology for reliability*, John Wiley & Sons, October 2009
7. Ali A. Chowdhury, Don O. Koval, *Power distribution system reliability-Practical methods and applications*, John Wiley & sons Inc., IEEE Press 2009
8. Richard E.Brown, *Electric power distribution reliability*, Taylor & Francis Group,LLC,2009.

9. Elmakias, David (Ed.) *New Computational Methods in Power System Reliability*, Studies in Computational Intelligence, Springer 2008
10. TurenGonen, *Electric power distribution system engineering*, McGraw Hill New York, 1986

EE6224D DISTRIBUTED PROCESSING OF POWER SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain functions of Distributed Energy Management Systems and Advantages of Distributed Processing

CO2: Design of Parallel and Distributed processing algorithms for vertically Integrated Power Systems and Restructured Power Systems

CO3: Apply parallel and distributed processing algorithms for load Flow analysis, state estimation and security assessment for power Systems

CO4: Design and implement distributed Control of Voltage and reactive Power and explain Transmission Congestion Management

Module 1: (9 hours)

Distributed Energy Management Systems: Functional Requirements of EMS - Complexity of Power Grid- Necessity for Distributed Processing - Vertically Integrated Power Systems-Central control center and Area control center - SCADA- - Distributed EMS- Restructured Power Systems- Advantages of Distributed Processing.

Module 2:(9 hours)

Parallel and Distributed Processing of Power systems: Parallel Systems- Distributed Systems- Comparison- Design of Parallel and Distributed algorithms- Distributed Processing of vertically Integrated Power Systems and Restructured Power Systems- Computer networks for Distributed Processing- Data Communication – Message Passing Interface

Module 3: (10 hours)

Parallel and distributed Load Flow: Mathematical Model- Parallel load flow Computation- Distributed load flow computation- System Partitioning and Algorithms- Parallel and distributed Load Flow for Distribution Systems-case studies and simulation results.

Parallel and distributed State Estimation: Components of State Estimation- Mathematical Model- Parallel State Estimation- Distributed State Estimation

Module 4: (11 hours)

Distributed Power System Security Analysis: Power System Security Analysis- - Distributed Contingency Selection, Distributed Static Security Analysis- Distributed Dynamic Security Analysis.

Distributed Control of Voltage and reactive Power- Decentralised closed loop primary control, distributed secondary voltage/VAR control, Reactive Power Bidding, Centralized Tertiary voltage / VAR optimization.

Transmission Congestion Management: Agent Based modeling – Multi Agent based Scheme for Congestion Management and Congestion mitigation.

References:

1. Mohammed Shahidehpour and Yauyu Wang, *Communication and Control in Electric Power Systems*, John Wiley & Sons, 2005.
2. Mariesa L. Crow, *Computational Methods for Electric Power Systems*, CRC Press, 2010.
3. Dimitri Bertsekas, John N. Tsitsiklis, *Parallel and Distributed Computation: Numerical Methods*, Prentice Hall Inc., 1989.
4. J. Arrilaga, C.P. Arnold, B.J. Harker, *Computer modelling of Electric Power Systems*. Wiley, New York, 1983.

5. A.J. Wood, B.F. Wollenberg, *Power Generation, Operation and Control*, John Wiley & Sons, New York, 1984.
6. John J. Grainger and William D. Stevenson, *Power System Analysis*, Tata McGraw-Hill, 2003.
7. Haadi A. Sadat, *Power System Analysis*, McGraw Hill Co. Ltd., India, 2000.
8. Mohammad Shahidehpour, M. Alomoush, *Restructured Electrical Power Systems: Operation: Trading, and Volatility*, CRC Press, 2001
9. George L. Kusic, *Computer Aided Power System Analysis,* Prentice Hall of India (P) Ltd., New Delhi, 1989.
10. Ali Abur, Antonio Gómez Expósito, *Power System State Estimation: Theory and Implementation*, CRC Press, 2004.

EE6226D HYBRID AND ELECTRIC VEHICLES

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain performance characteristic and model dynamics of hybrid and electric vehicles
CO2: Analyse the architecture of drive trains and electric propulsion units of electric and hybrid vehicles
CO3: Analyse various energy storage devices used in hybrid and electric vehicles and select the electric drive system
CO4: Explore energy management strategies used in hybrid and electric vehicles

Module 1: (9 hours)

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 - Conventional Vehicles: Basics of vehicle performance, vehicle power source characterization, transmission characteristics, mathematical models to describe vehicle performance.

Module 2: (10 hours)

Hybrid and Electric Drive-trains: Basic concept of traction, introduction to various drive-train topologies, power flow control in 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.

Module 3: (10 hours)

Energy Storage: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Analysis of various energy storage devices – Battery, Fuel Cell, Super, Flywheel - Hybridization of different energy storage devices.

Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor and power electronics, selecting the energy storage technology, Communications, supporting subsystems

Module 4: (10 hours)

Energy Management Strategies: Introduction to energy management strategies used in hybrid and electric vehicles, classification, comparison and implementation issues of energy management strategies.

Case Studies: Design of a Hybrid Electric Vehicle (HEV) and Battery Electric Vehicle (BEV).

References:

1. I. Husain, *Electric and Hybrid Electric Vehicles*, CRC Press, 2003
2. M. Ehsani, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design*, CRC Press, 2005
3. A. E. Fuhs, *Hybrid Vehicles and the Future of Personal Transportation*, CRC Press, 2009
4. C. C. Chan and K. T. Chau, *Modern Electric Vehicle Technology, Oxford Science Publication*, 2001
5. G. Lechner and H. Naunheimer, *Automotive Transmissions: Fundamentals, Selection, Design and Application*, Springer, 1999

6. Gianfranco, *Electric and Hybrid Vehicles: POWER SOURCES, MODELS, SUSTAINABILITY, INFRASTRUCTURE AND THE MARKET*, Pistoia Consultant, Rome, Italy, 2010
7. M. H. Rashid, *Power Electronics: Circuits, Devices and Applications*, 3rd ed., Pearson, 2004
8. V. R. Moorthi, *Power Electronics: Devices, Circuits and Industrial Applications*, Oxford University Press, 2007
9. R. Krishnan, *Electric motor drives: modeling, analysis, and control*, Prentice Hall, 2001
10. P. C. Krause, O. Wasynczuk, S. D. Sudhoff, *Analysis of electric machinery*, IEEE Press, 1995
11. L. Guzella, A. Sciarretta, *Vehicle Propulsion Systems*, Springer, 2007

EE6302D ADVANCED POWER ELECTRONIC CIRCUITS

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:
CO1: Analyse and design Load Commutated CSI and PWM CSI.
CO2: Demonstrate the working of series Inverters.
CO3: Recommend the Switched Mode Rectifiers and APFC for any application.
CO4: Explain the resonant mode converters and their operation and control.

Module 1: High power converters (10 hours)

Multi-Level Inverters of Diode Clamped Type and Flying Capacitor Type and suitable modulation strategies - Multi-level inverters of Cascade Type
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:Choppers(9 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.
AC Choppers, Application of AC and DC choppers.

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 interfaces and control

Module 3: (10 hours)

Single Phase and 3 Phase Boost type APFC - DCM, BCM, CCM design and control strategies, Single Phase and 3 Phase bidirectional converters in rectifier mode - control of DC voltage - control of Input Current.
Hysteresis control in Single Phase and 3 Phase - Frequency control in hysteresis, Constant switching frequency control methods.

Module 4: **(10 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.
Resonant converters for induction heating.

Textbooks and References:

1. Ned Mohan "*Power electronics : converters, applications, and design*" John Wiley and Sons, 2006
2. Bin Wu , "*High-Power Converters And Ac Drives*", IEEE Press, A John Wiley & Sons, Inc., Publication,
3. Rashid "*Power Electronics*" Prentice Hall India 2007.
4. G.K.Dubey "*Thyristorised Power Controllers*" Wiley Eastern Ltd., 2005, 06.
5. Dewan&Straughen*"Power Semiconductor Circuits*" John Wiley &Sons., 1975.
6. G.K. Dubey& C.R. Kasaravada*"Power Electronics & Drives"* Tata McGraw Hill., 1993.

7. IETE Press Book *Power Electronics* Tata McGraw Hill, 2003
8. Cyril W Lander "*Power Electronics"* McGraw Hill., 2005.
9. B. K Bose "*Modern Power Electronics and AC Drives*" Pearson Education (Asia)., 2007
10. Abraham I Pressman "*Switching Power Supply Design*" McGraw Hill Publishing Company., 2001.
11. Daniel M Mitchell "*DC-DC Switching Regulator Analysis*" McGraw Hill Publishing Company.-1988

EE6304D MODERN DIGITAL SIGNAL PROCESSORS

Pre -Requisite: Nil.

L	T	P	C
3	1	0	3

Total Hours: 39

Course Outcomes:
CO1: Design a system using digital signal processors
CO2: Analyse and understand digital signal processors architectures.
CO3 : Program various DSP processors using IDEs.
CO4: Utilise the advantages of modern digital signal processors for power electronic applications.

Module 1: Introduction to Digital Signal Processors(DSP) (12 hours)

Features of Digital Signal Processors, Modern trends in DSP: Von Newmann versus Harvard architecture, Architectures of superscalar and VLIW fixed and floating point processors, New Digital Signal Processing hardware trends, Selection of DS processors.
Internal details of DSP using Texas Instruments DSP (TMS330C6000 Series) as a tool: DSP Architecture, CPU Data Paths and Control, Internal Data/Program Memory. On chip peripherals and its programming details: Timers - Multi channel buffered serial ports - Extended Direct Memory Access, Interrupts, Pipelining.

Module 2:Programming the DSP(14 hours)

Texas Instruments IDE - CC Studio - Introduction to the C6713 DSK- Review of FIR filtering: FIR filter design techniques and tools, Review of IIR filtering: IIR filter design techniques and tools, Sampling, quantization and working with the AIC23 codec, Writing efficient code: optimizing compiler - effect of data types and memory map. TMS320C6713 Assembly language Programming: Instructions Set and Addressing Modes – Linear Assembly. Interfacing CC Studio with Matlab.

Module 3:Current trend in Digital Signal Processors (13 hours)

Motor Control Digital Signal Processing Solutions Using the TMS320F240DSP-Controller.Architecture of TMS320C2XX series DSP and its applications. Architecture trends of other DSP processors, Analog Devices DS processors: ADSP-2105 digital signal processor for motor control applications, Microchip dsPIC controllers for power electronics applications. Other major vendors in the DSP market and the latest trends.

References:

1. On-line TI materials for the TI C6713 DSK board: http://www.ti.com
2. NaimDahnoun‘*Digital Signal Processing Implementation using the TMS320C6000 DSP Platform’*, 1st Edition
3. R. Chassaing, ‘*Digital Signal Processing and Applications with the C6713 and C6416 DSK*’, John Wiley and Sons, Inc., New York, 2004
4. Sen M. Kuo and Woon-Seng Gan. ‘*Digital Signal Processors: Architectures, Implementations, and Applications’*,
5. David J Defatta J, Lucas Joseph G &Hodkiss William S ; ‘*Digital Signal Processing: A System Design Approach*’, 1st Edition; John Wiley
6. A.V. Oppenheim and R.W. Schafer, Discrete-Time Signal Processing, Second edition, Prentice-Hall,Upper Saddle River, NJ, 1989
7. John G Proakis, Dimitris G Manolakis Introduction to Digital Signal Processing, 1st Edition.
8. On-line Microchip materials: http://www.microchip.com/design-centers/intelligent-power

EE6306D POWER ELECTRONIC DRIVES

Pre-requisite: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:

CO1: Choose a suitable Motor and Power Electronic Converter system from a description of drive requirement - involving load estimation, load cycle considerations, thermal aspects and motor-converter matching.
CO2: Design various DC and AC machines used in drives.
CO3: Demonstrate Electrical Motor operation using Generalized machine theory.
CO4: Explain the working and design of various converters used in Electrical Drives.

Module – 1: **(10 hours)**

Introduction to Motor Drives - Components of Power Electronic Drives – Criteria for selection of Drive components - Match between the motor and the load - Thermal consideration - Match between the motor and the Power Electronics converter - Characteristics of mechanical systems - stability criteria

Module – 2: **(10hours)**

D.C Motor Drives - System model motor rating - Motor-mechanism dynamics - Drive transfer function – Drives control-speed controller design-Effect of armature current waveform - Torque pulsations – Adjustable speed dc drives - Chopper fed and 1-phase converter fed drives - Effect of field weakening.

Module – 3: **(11 hours)**

Induction Motor Drives - Basic Principle of operation of 3 phase motor - Equivalent circuit – MMF Space harmonics due to fundamental current - Fundamental spatial mmf distributions due to time harmonics -Simultaneous effect of time and space harmonics - Speed control by varying stator frequency and voltage -Impact of non-sinusoidal excitation on induction motors - Variable frequency converter classifications -Variable frequency PWM-VSI drives - Variable frequency square wave VSI drives - Variable frequency CSI drives - Comparison of variable frequency drives - Line frequency variable voltage drives - Soft start of induction motors - Speed control by static slip power recovery. - Vector control of 3 phase squirrel cage motors - Principle of operation of vector control

Module – 4: (8 hours)

Synchronous Motor Drives - Introduction - Basic principles of synchronous motor operation methods of control - operation with field weakening - load commutated inverter drives. PMSM Drives, Switched reluctance Drive.

Textbooks and References:

1. Ned Mohan ,"*Power Electronics*" ,Wiley 2006
2. R Krishnan*'Electric Motor Drives, Modeling, Analysis, and Control*,", Pearson Education,2001
3. G.K.Dubey&C.R.Kasaravada ,"*Power Electronics & Drives*", Tata McGraw Hill,1993.
4. W.Shephered, L N HulleyCambride,'*Power Electronics & Control of Motor'* , University Press,2005.
5. Dubey*, 'Power Electronics Drives'* ,Wiley Eastern,1993.
6. Chilikin M, '*Electric drives'* , Mir publications, 2nd edition,1976

EE6323D DIGITAL SIMULATION OF POWER ELECTRONIC SYSTEMS

Pre-requisite: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course outcomes:

CO1: Develop mathematical model of power electronic switches and electrical machines.
CO2: Model and simulate Power Electronic Systems using software packages such as PSpice, MATLAB-Simulink & Saber
CO3: Design and simulate power electronic systems using PSpice.
CO4: Illustrate power electronic system design and simulation using MATLAB- Simulink.
CO5: Analyse and design power electronic systems and simulate using Saber

Module 1:Principles of Modeling Power Semiconductor Devices(10 hours)

Macro models versus Micro models– 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:PSpice(9 Hours)

Circuit Analysis Software MicroSimPSpice 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: PSpice andMATLAB(9 Hours)

MicroSimPSpice A/D - Preparing a Schematic for Simulation - Creating Symbols - Creating - Models - Analog Behavioral Modeling - Setting Up and Running analyses - Viewing Results - Examples of PowerElectronic Systems. MATLAB SIMULINK in Power system.

Module 4: Simulation with Saber(11 Hours)

Design Creation and Simulation with Saber Designer - 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 Saber Scope - Analysing waveforms with Saber Scope - Performing Measurements on a waveform - Varying a Parameter - Displaying the Parameter Sweep Results - Measuring a Multi-Member Waveform - Simulation Examples of Power Electronic Systems.

Text Books and References:

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

EE6327D IMPLEMENTATION OF DSP ALGORITHMS

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:
CO1: Illustrate the architecture of DSP systems, various transforms and algorithms in DSP.
CO2: Analyse and design digital filters and implement them.
CO3: Explain about Quantization Noise, and significance of Sampling rate and its conversion.
CO4: Design DSP algorithms and implement in PDSP / FPGA systems

Module 1: INTRODUCTION and TRANSFORMS(13 hours)

Overview of Digital Signal Processing, Introduction to MATLAB , Applications of Digital Signal Processing; Discrete-time signals and systems - Discrete-time Signals, Discrete Systems, Convolution, Difference Equations; The Discrete-Time Fourier Analysis - The Discrete-Time Fourier Transform (DTFT), The Properties of the DTFT, The Frequency Domain Representation of LTI Systems, Sampling and Reconstruction of Analog Signals; The*Z*-Transform - The Bilateral *Z*-Transform, Important Properties of the *Z*-Transform, Inversion of the *z*-Transform, System Representation in the *Z*-Domain, Solutions of the Difference Equations; The Discrete Fourier Transform - The Discrete Fourier Series, Sampling and Reconstruction in the *Z*-Domain, The Discrete Fourier Transform, Properties of the Discrete Fourier Transform, Linear Convolution Using the DFT, The Fast Fourier Transform.

Module 2: DIGITAL FILTER IMPLEMENTATION (14 hours)

Implementation of discrete-time filters - Basic Elements, IIR Filter Structures, FIR Filter Structures, Lattice Filter Structures, Overview of Finite-Precision Numerical Effects, Representation of Numbers, The Process of Quantization and Error Characterizations, Quantization of Filter Coefficients; FIR filter design - Preliminaries, Properties of Linear-phase FIR Filters, Window Design techniques, Frequency Sampling Design Techniques, Optimal Equiripple Design Technique, IIR filter design, Some Preliminaries, Some Special Filter Types, Characteristics of Prototype Analog Filters, Analog-to-Digital Filter Transformations, Lowpass Filter Design, Frequency-band Transformations.

Module 3: SAMPLING RATE CONVERSION(12 hours)

Introduction, Decimation by a Factor *D,* Interpolation by a Factor *I,* Sampling Rate Conversion by a Rational Factor *I/D,* FIR Filter Designs for Sampling Rate Conversion, FIR Filter Structures for Sampling Rate Conversion; Round-off Effects in Digital Filters - Analysis of A/D Quantization Noise, Round-off Effects in IIR Digital Filters, Round-off Effects in FIR Digital Filters; Applications in Adaptive Filtering - LMS Algorithm for Coefficient Adjustment, System Identification or System Modeling, Suppression of Narrowband Interference in a Wideband Signal, Adaptive Line Enhancement, Adaptive Channel Equalization.

Note : Use MATLAB as a tool to implement all these DSP concepts and obtain the resulting plots. Convert this Matlab code and implement in PDSP and / or FPGA systems.

Textbooks and References:

1. Vinay K. Ingle ,John G. Proakis : ‘*Digital Signal Processing Using MATLAB®’*, Cengage Learning - Third Edition, ISBN-13: 978-1-111-42737-5.
2. Dimitris G Manolakis, John G. Proakis: ‘*Digital Signal Processing : Principles, Algorithms, and Applications’*, 4^{th} Edition, Pearson, 2007, ISBN: 9788131710005, 8131710009.
3. HazarathaiahMalepati: ‘*Digital Media Processing: DSP Algorithms Using C’*, Elsevier Science Publisher, ISBN: 9781856176781, 1856176789.

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

EE6329D ADVANCED MICROPROCESSOR BASED SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

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Course Outcomes:

CO1: Illustrate the working of advanced microprocessors/controllers.
CO2: Program a processor in assembly language and develop an advanced processor based system.
CO3: Configure and use different peripherals in a digital system.
CO4: Explain how to compile, debug and execute Programs.

Module 1: Introduction (8 hours)

Technology trend in microprocessors - performance measurement –Comparing and summarizing performance - quantitative principles of computer design – Amdahl's law - Case studies.

History of the x86 family - Instruction Set architecture of a typical advanced x86 processor – using MASM32 for 32 bit assembly programming of x86 architectures

Module 2: 80386 to Pentium (8 hours)

Enhancements of 80386, Hardware Features, Protected virtual addressing mode -Virtual Memory, Memory Management Unit, Converting a Logical Address to a Physical Address, Calculating the size of the Logical Address Space, Protection, Multi Tasking, Interrupts of 80386, Privileged Instructions, The Enhanced Features of 80486, Data Alignment, The Pentium Processor, Pentium Pro, Pentium-II And Pentium-III, Pentium-IV, Latest Trends in Microprocessor Design

Module 3: ARM Introduction and Pipeline structures(13 hours)

Instruction Set Architecture (ISA) and ARM History, ARM architecture, Stack implementation in ARM, Endians, ARM organization and Implementation, Different Types of Instructions, ARM Instruction Set and Thumb Instruction set. Thumb state, Thumb Programmers model, Thumb Implementation, Thumb Applications. Thumb Instructions, Assembly Language Programming, condition codes, Data processing Instructions, High- Level Language Programming, System Development using ARM.Pipeline Hazards Interrupts and Exceptions, Exception Handlers, Reset Handling.Aborts, software Interrupt Instruction, undefined instruction exception. Interrupt Handling schemes, Interrupt Latency.

Module 4: ARM Memory and Hardware interfacing. (10 hours)

Memory Hierarchy, Cache and Memory Management and Protection, Digital Signal Processing on ARM, Peripheral Programming and system design for a specific ARM processor (ARM7/9), PWM generation and Motor control using ARM processor board. .

Textbooks and References:

1. Lyla B.Das'*The x86 Microprocessors –Architecture Programming and Interfacing -8086 to Pentium*', Pearson Education , 2010.
2. Daniel W. Lewis , '*Fundamentals of Embedded Software with the ARM Cortex-M3*', PEARSON, 1st Edition, 2015, ISBN: 9789332549937, 9332549931
3. Jonathan W Valvano, '*Embedded Systems: Introduction to Arm® Cortex(TM)-M3 Microcontrollers*' , 2012.

4. Vincent Mahout, '*Assembly Language Programming: ARM Cortex-M3'* , Wiley , 2012
5. JurijSilc, Borut Rob c, Theo Ungerer .Processor Architecture –From DataFlow to Super scalar and Beyond
6. Shibu K.V. Introduction to Embedded Systems Tata McGraw Hill, 2009
7. Robert Ashby *Designer's Guide to the Cypress PSoCNewnes* (An imprint of Elsevier), 2006
8. Sloss, Symes, Wright, ARM System Developer's Guide, Elsevier, 2014, ISBN: 9781493303748.
9. Oliver H. Bailey, *The Beginner's Guide to PSoC Express* Timelines Industries Inc.
10. Van Ess, Currie and Doboli Laboratory Manual for Introduction to Mixed-Signal, Embedded Design, Alphagraphics, USA
11. Steve Furber*ARM System-on-chip Architecture* ,Second Edition Pearson Education,2007
12. William Hohl ARM Assembly Language Programming CRC Press,2009
13. Andrew Sloss, Dominic Symes, Christ Wright, *ARM System Developer's guide –Designing and optimizing software*Elseiver Publishers ,2008
14. Andrew N. SLOSS, Dominic *SYMES and Chris WRIGHT: ARM System Developers Guide*, Designing and Optimizing System Software. ELSEVIER, 2004
15. Steve Furber*, ARM System-on-Chip Architecture*, Second Edition, PEARSON, 2013
16. Manuals and Technical Documents from the ARM Inc, web site.
17. Hennesy J. L. &Pattersen D. A., *Computer Architecture: A Quantitative approach*, 4/e, Elseiver Publications, 2007

EE6401D ENERGY AUDITING & MANAGEMENT

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: Recognize the role of energy managers and use the skills and techniques required to implement energy management.

CO2: Identify and quantify the energy intensive business activities in an organization.

CO3: Describe the standard methodologies for measuring energy in the workplace and energy audit Instruments

CO4: Analyze energy efficient control scheme for electric motors and perform case study on load matching and selection of motors.

CO5: Explain the energy conservation methods in motors, pumps, fans, compressors, transformers, geysers, lighting schemes, air conditioning, refrigeration, cool storage.

CO6: Conduct a walkthrough audit in various industries.

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: (10 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: (10 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: (10 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. Y P Abbi and Shashank Jain, '*Handbook on Energy Audit and Environment Management*', TERI, 2006
2. Albert Thumann, William J. Younger, Terry Niehus , '*Handbook of Energy Audits*', 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. Barney L. Capehart, Wayne C. Turner , William J. Kennedy, '*Guide to Energy Management'*, Fairmont Press, 6th edition ,April 23, 2008.
17.Donald R. Wulfinghoff*, 'Energy Efficiency Manual: for everyone who uses energy, pays for utilities, designs and builds, is interested in energy conservation and the environment'*, Energy Institute Press March 2000.
18.Albert Thumann., William J. Younger, '*Handbook of Energy Audits'*, Fairmont Press, 7thEdition, 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. Albert Thuman, D. Paul Mehta , '*Handbook of Energy Engineering'*, Fairmont Press, 6th edition , June 24, 2008.

EE6405D ARTIFICIAL INTELLIGENCE & AUTOMATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Identify potential areas for automation and justify need for automation
CO2: Select suitable major control components required to automate a process or an activity
CO3: Identify suitable automation hardware for the given application
CO4: Explain Artificial Intelligence and Identify systems with Artificial Intelligence.
CO5: Implement classical Artificial Intelligence techniques, such as search algorithms, minimax algorithm, neural networks, tracking, robot localization.

Module 1: (10 hours)

Introduction: Overview and Historical Perspective, Turing test, Physical Symbol Systems and the scope of Symbolic AI, Agents. State Space Search: Depth First Search, Breadth First Search, DFID. Heuristic Search: Best First Search, Hill Climbing, Beam Search, Tabu Search. Randomized Search: Simulated Annealing, Genetic Algorithms, Ant Colony Optimization. Finding Optimal Paths: Branch and Bound, A*, IDA*, Divide and Conquer approaches, Beam Stack Search.

Module 2: (9 hours)

Problem Decomposition: Goal Trees, AO*, Rule Based Systems, Rete Net. Game Playing: Minimax Algorithm, AlphaBeta Algorithm, SSS*. Planning and Constraint Satisfaction: Domains, Forward and Backward Search, Goal Stack Planning, Plan Space Planning, Graphplan, Constraint Propagation. Logic and Inferences: Propositional Logic, First Order Logic, Soundness and Completeness, Forward and Backward chaining.

Module 3: (10 hours)

Automation – Introduction - Automation in Production System, Principles and Strategies of Automation, Basic elements of an Automated System, Advanced Automation Functions, Levels of Automations. Flow lines & Transfer Mechanisms, Fundamentals of Transfer Lines. (SLE: Analysis of Transfer Lines). Automated Manufacturing Systems: Components, Classification and Overview of Manufacturing Systems, Manufacturing Cells, GT and Cellular Manufacturing, FMS, FMS and its Planning and Implementation.

Module 4: (10 hours)

Control Technologies in Automation: Industrial Control Systems, Process Industries VS Discrete Manufacturing Industries, Continuous VS Discrete Control, Computer Process and its Forms. (SLE: Sensors, Actuators and other Control System Components). Computer Based Industrial Control: Introduction & Automatic Process Control, Building Blocks of Automation Systems: LAN, Analog & Digital I/O Modules, SCADA Systems & RTU. Distributed Control System - functional requirements, configurations & some popular Distributed Control Systems.

References:

1. M.P.Groover, '*Automation, Production Systems and Computer Integrated Manufacturing*', Pearson Education, 5th edition, 2009.
2. Krishna Kant, '*Computer Based Industrial Control*', EEE-PHI,2nd edition,2010
3. Tiess Chiu Chang & Richard A. Wysk , '*An Introduction to Automated Process Planning Systems*'.
4. Viswanandham, '*Performance Modeling of Automated Manufacturing Systems*', PHI, 1st edition, 2009.
5. Deepak Khemani, '*A First Course in Artificial Intelligence*', McGraw Hill Education (India), 2013
6. Stefan Edelkamp and Stefan Schroedl. '*Heuristic Search: Theory and Applications*', Morgan Kaufmann, 2011.

7. John Haugeland, '*Artificial Intelligence: The Very Idea*', A Bradford Book, The MIT Press, 1985.
8. Pamela McCorduck, '*Machines Who Think: A Personal Inquiry into the History and Prospects of Artificial Intelligence',* A K Peters/CRC Press; 2 edition, 2004.
9. Zbigniew Michalewicz and David B. Fogel, '*How to Solve It: Modern Heuristics*', Springer; 2nd edition, 2004.
10. Judea Pearl, 'Heuristics: *Intelligent Search Strategies for Computer Problem Solving*', Addison-Wesley, 1984.
11. Elaine Rich and Kevin Knight., '*Artificial Intelligence*', Tata McGraw Hill, 1991.
12. Stuart Russell and Peter Norvig, '*Artificial Intelligence: A Modern Approach*', 3rd Edition, Prentice Hall, 2009.
13. Eugene Charniak, Drew McDermott, '*Introduction to Artificial Intelligence*', Addison-Wesley, 1985.
14. Patrick Henry Winston, '*Artificial Intelligence*', Addison-Wesley, 1992.

EE6421D SMART GRID TECHNOLOGIES AND APPLICATIONS

Prerequisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain various smart resources, smart meters and other smart devices.
CO2: Describe modern power distribution system functions.
CO3: Identify suitable communication networks for smart grid applications

Module 1: (8 hours)

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

Module 2: (11 hours)

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

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

Module 3: (9 hours)

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

Module 4: (11 hours)

Elements of communication and networking – architectures, standards, PLC, Zigbee, GSM, BPL, Local Area Network (LAN) - House Area Network (HAN) - Wide Area Network (WAN) - Broadband over Powerline (BPL) - IP based Protocols - Basics of Web Service and CLOUD Computing, Cyber Security for Smart Grid

References:

1. Stuart Borlase, '*Smart Grid: Infrastructure, Technology and Solutions'*, CRC Press 2012.
2. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, '*Smart Grid: Technology and Applications'*, Wiley, 2012.
3. Mini S. Thomas, John D McDonald, '*Power System SCADA and Smart Grids'*, CRC Press, 2015
4. Kenneth C.Budka, Jayant G. Deshpande, Marina Thottan, '*Communication Networks for Smart Grids'*, Springer, 2014.

EE6422D ENGINEERING OPTIMIZATION AND ALGORITHMS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Apply mathematical and numerical techniques of optimization theory to concrete Engineering problems.
CO2: Create, solve and analyze the optimization problems.
CO3: Describe the mathematical properties of general linear programming problems and obtain the solution of linear programming problems using appropriate techniques.
CO4: Formulate real-world problems as Linear Programming models, apply the simplex method and dual simplex algorithms in solving the standard LP problem and interpret the results obtained.
CO5: Apply linear programming in various engineering applications
CO6: Identify solution algorithms to find the best possible solution in nonlinear decision models

Module 1: (10 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: (10 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: (9 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.

EE6426D DISTRIBUTION SYSTEMS MANAGEMENT AND AUTOMATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Describe the architecture, functions and implementation strategies of Distribution Automation Systems and Distribution Management Systems.

CO2: Apply Custom power devices for improving power quality and explain the issues related to the integration of Distributed Generation and Custom Power components in a distribution system.

CO3: Evaluate the performance of electrical distribution system on the basis of reliability indices calculation.

CO4: Perform electrical distribution system design for industrial and commercial buildings with emphasis given to Electrical Safety and Earthing Practices.

CO5: Describe the wireless and wired communication systems, communication protocols and architectures for control and automation of Distribution system.

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: (9 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: (11 Hours)

Communication Systems for Control and Automation- Wireless and wired Communications- DA Communication Protocols, Architectures and user interface-Case Studies

Module 4: (9 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 Gone, '*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. IEEE Standerd 739 . '*Recommended Practice for Energy Conservation and Cost Effective Planning in Industrial Facilities'*. 1984
7. G H Heydt , '*Electric Power Quality'* , McGram Hill, 2007
8. Wilson K. Kazibwe and Musoke H Semdaula , '*Electric Power Quality Control Techniques,'* Van Nostarand Reinhold New York, 2006
9. Lakervi & E J Holmes, '*Electricity distribution network design'*, 2nd Edition Peter Peregrimus Ltd. 1995

EE6428D SCADA SYSTEMS & APPLICATIONS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Describe the basic tasks of Supervisory Control Systems (SCADA) as well as their typical Applications.
CO2: Explain SCADA architecture and SCADA system components
CO3: Describe the single unified standard architecture IEC 61850
CO4: Explain SCADA communication system, various industrial communication technologies and open standard communication protocols.
CO5: Apply SCADA systems in transmission and distribution sectors and industries.

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: (10 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: (10 hours)

SCADA Architecture: Various 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: (9 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.

EE6429D WIRELESS & SENSOR NETWORKS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Apply the knowledge of wireless sensor networks(WSN) to various application areas.
CO2: Design and implement WSN.
CO3: Conduct performance analysis of WSN and manage WSN.
CO4: Formulate and solve problems creatively in the area of WSN.

Module 1: (11 hours)

Introduction: Introduction to Sensor Networks, unique constraints and challenges, Advantage of Sensor Networks, Applications of Sensor Networks, Mobile Adhoc NETworks (MANETs) and Wireless Sensor Networks, Enabling technologies for Wireless Sensor Networks. Sensor Node Hardware and Network Architecture: Single-node architecture, Hardware components & design constraints, Operating systems and execution environments

Module 2: (10 hours)

Introduction to TinyOS and nesC - Network architecture, Optimization goals and figures of merit, Design principles for WSNs, Service interfaces of WSNs, Gateway concepts. Deployment and Configuration: Localization and positioning, Coverage and connectivity, Single-hop and multi-hop localization, self configuring localization systems, sensor management

Module 3: (10 hours)

Network Protocols: Issues in designing MAC protocol for WSNs, Classification of MAC Protocols, S-MAC Protocol, B-MAC protocol, IEEE 802.15.4 standard and Zig Bee, Dissemination protocol for large sensor network. Routing protocols: Issues in designing routing protocols, Classification of routing protocols, Energy-efficient routing, Unicast, Broadcast and multicast, Geographic routing.

Module 4: (8 hours)

Data Storage and Manipulation: Data centric and content based routing, storage and retrieval in network, compression technologies for WSN, Data aggregation technique. Applications: Detecting unauthorized activity using a sensor network, WSN for Habitat Monitoring.

References:

1. Holger Kerl, Andreas Willig, ‘*Protocols and Architectures for Wireless Sensor Network’*, John Wiley and Sons, 2005 (ISBN: 978-0-470-09511-9).
2. Raghavendra, Cauligi S, Sivalingam, Krishna M., Zanti Taieb, ‘*Wireless Sensor Network’*, Springer 1st Ed. 2004 (ISBN: 978-4020-7883-5).
3. Feng Zhao, Leonidas Guibas, ‘*Wireless Sensor Network’*, Elsevier, 1st Ed. 2004 (ISBN: 13- 978-1-55860-914-3)
4. Kazem, Sohraby, Daniel Minoli, Taieb Zanti, ‘*Wireless Sensor Network: Technology’, Protocols and Application*, John Wiley and Sons 1st Ed., 2007 (ISBN: 978-0-471-74300-2).
5. B. Krishnamachari, ‘*Networking Wireless Sensors’*, Cambridge University Press.
6. N. P. Mahalik, ‘*Sensor Networks and Configuration: Fundamentals, Standards, Platforms, and Applications’*, Springer Verlag.

EE6430D NETWORK & DATA SECURITY

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Discuss about information security governance, and related legal and regulatory issues
CO2: Identify external and internal security threats to an organization
CO3: To be familiar with information security awareness and a clear understanding of its importance
CO4: Discover and analyze the threats to an organization and select suitable solution strategies.

Module 1: (10 hours)

Introduction: Basic objectives of cryptography, secret-key and public-key cryptography, Block ciphers: Modes of operation, DES and its variants, AES, linear and differential cryptanalysis, stream ciphers, message digest algorithms: properties of hash functions, MD5 and SHA-1, keyed hash functions, attacks on hash functions.

Module 2: (11 hours)

Modular arithmetic, gcd, primality testing, Chinese remainder theorem, finite fields. Intractable problems: Integer factorization problem, RSA problem, discrete logarithm problem, DiffieHellman problem, Publickey encryption: RSA, Elliptic curve cryptography. Key exchange: Diffie-Hellman algorithms. Digital signatures: RSA, DSS, DSA, ECDSA, blind signatures, threshold cryptography, key management.

Module 3:(13 hours)

Network Security – Electronic Mail Security- Pretty Good Privacy – S/MIME – IP security – overview and architecture – authentication header – encapsulating security payload – combing security associations – web security requirements Secure Socket Layer and Transport Layer Security – secure electronic transactions, Authentication applications: X-509, Kerberos, RADIUS.

Module 4: (5 hours)

Wireless network security - WEP, WPA2 (802.11i), security in Bluetooth.

References:

1. Stallings, W., '*Cryptography and network security: principles and practice",.* 4th ed. Upper Saddle River: Prentice Hall, 2006. ISBN 0-13-187316-4.
2. Stallings,' *Network security essentials applications and standards*', Pearson education, 1999.
3. Menezes, A. J., Van Oorschot, P. C.; Vanstone, S. A., '*Handbook of applied cryptography'*, Boca Ratón [etc.]: CRC Press, 1997. ISBN 0-8493-8523-7.
4. Stajano, F.*, 'Security for ubiquitous computing*', Chichester: John Wiley and Sons, 2002. ISBN 0-470- 84493-0.

EE6432D ADVANCED ALGORITHMS AND DATA STRUCTURE ANALYSIS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain algorithmic techniques such as brute force, greedy, and divide and conquer.
CO2: Apply advanced abstract data type (ADT) and data structures in solving real world problems.
CO3: Devise complete algorithmic solution to a given problem effectively combining the fundamental data structures and algorithmic techniques.

Module 1: (9 hours)

Review of order notation & growth of functions, recurrences, probability distributions, Average case analysis of algorithms, Basic data structures such as stacks, queues, trees, graphs linked lists, and applications, priority queues.

Module 2: (8 hours)

Direct access tables and hash tables, hash functions and relates analysis, Binary Search trees and Operations, AVL Trees and balancing operations, R B Trees, properties, operations. Dynamic Graphs, Strings, Succinct. Dynamic optimality, Memory hierarchy.

Module 3: (11 hours)

Quick sort randomized version, searching in linear time, More graph algorithms – maximal independent sets, colouring vertex cover, introduction to perfect graphs.

Module 4: (11 hours)

Algorithmic paradigms Greedy Strategy, Dynamic programming, Backtracking, Branch-and-Bound, Randomized algorithms. Generic programming methodology and algorithm design – microprogramming - ADC, Quantization, word length issues, floating point numbers, etc

References:

1 H. S. Wilf, *Algorithms and complexity*, Prentice hall.
2 T. H. Cormen, C. E. Leiserson, R. L. Rivest, *Introduction to Algorithms*, Prentice hall.

EE6434D INTERNET OF THINGS AND APPLICATIONS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Discover the application areas of IOT ·
CO2: Realize the revolution of Internet in Mobile Devices, Cloud & Sensor Networks
CO3: Describe the building blocks of Internet of Things and characteristics
CO4: Explain cloud based sensor data analysis

Module 1: (10 Hours)

Elements of an IoT ecosystem. Technology drivers, Business drivers. Typical IoT applications. Trends and implications. Overview of IoT supported Hardware platforms such as: Raspberry pi, ARM Cortex Processors, Arduino and Intel Galileo boards. IoT architecture: History of IoT, M2M - Machine toMachine, Web of Things, IoT protocols. Internet of Things (IoT) and Web of Things (WoT). Internet and Web Layering
Business aspects of the Internet of Things. Representational State Transfer (REST) and Activity Streams, Business Cases & Concepts Persuasive Technologies & Behavioral Change IoT Communication Protocols Big Data and Semantic Technologies

Module 2: (10 Hours)

Overview and working principle of Wired Networking equipment - Router, Switches, Overview and working principle of Wireless Networking equipment – Access Points, Hubs, etc. Linux Network configuration concepts: Networking configurations in Linux Accessing Hardware &Device Files interactions.

Module 3: (12 Hours)

Network Fundamentals: Anatomy of a Sensor Network, Examples of Sensor Networks, Topology of a Sensor Network Communication Media. Wired Networks, Wireless Networks, Hybrid Networks. Types of Sensor Nodes, How Sensors Measure Storing Sensor Data. XBee Primer, Building an XBee-ZB Mesh Network, Arduino-Based Sensor Nodes,Hosting Sensors with Raspberry Pi

Module 4: (IoT tutorial and mini-project) (7 Hours)

Storing Sensor Data, Storage Methods - Local Storage Options for the Arduino, Local Storage Options for the Raspberry Pi, Remote Storage Options, MySQL
Local processing on the sensor nodes.

- Connecting devices at the edge and to the cloud.
- Processing data offline and in the cloud.
- Mini-project: Designing an IoT system

References :

1. J. Biron and J. Follett, '*Foundational Elements of an IoT Solution*', O'Reilly Media, 2016.
2. Keysight Technologies, '*The Internet of Things: Enabling Technologies and Solutions for Design and Tes't*, Application Note, 2016.
3. Charles Bell, '*Beginning Sensor Networks with Arduino and Raspberry Pi*', Apress, 2013.
4. D. Evans, '*The Internet of Things: How the Next Evolution of the Internet Is Changing Everything*', Cisco Internet Business Solutions Group, 2011
5. McKinsey& Company, '*The Internet of Things: Mapping the value beyond the hype*', McKinsey Global Institute, 2015

6. European Alliance for Innovation (EAI), '*Internet of Things: Exploring the potential'*, Innovation Academy Magazine, Issue No. 03, 2015
7. Digital Greenwich, '*Greenwich Smart City Strategy'*, 2015
8. ITU and Cisco, '*Harnessing the Internet of Things for Global Development'*, A contribution to the UN broadband commission for sustainable development

EE6436D INDUSTRIAL LOAD MODELLING & CONTROL

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the load control techniques in industries and its application.
CO2: Explain different types of industrial processes and optimize the process using tools like LINDO and LINGO.
CO3: Apply load management technique to reduce the demand of electricity during peak time.
CO4: Analyse different energy saving opportunities in industries.
CO5: Apply the techniques of reactive power control in industries and analyze different power factor improvement methods.
CO6: Explain the mathematical modelling and profiling of various loads such as cool storage, cooling and heating loads.

Module 1: (10 hours)

Electric Energy Scenario-Demand Side Management-Industrial Load Management; Load Curves-Load Shaping Objectives-Methodologies-Barriers; Classification of Industrial Loads- Continuous and Batch processes -Load Modelling; Electricity pricing – Dynamic and spot pricing -Models;

Module 2: (10 hours)

Direct load control- Interruptible load control; Bottom up approach- scheduling- Formulation of load models- optimisation and control algorithms - Case studies;

Reactive power management in industries-controls-power quality impacts-application of filters;

Module 3: (10 hours)

Cooling and heating loads- load profiling- Modeling- Cool storage-Types-Control strategies-Optimal operation-Problem formulation- Case studies;

Module 4: (9 hours)

Captive power units- Operating and control strategies- Power Pooling- Operation models; Energy Banking- Industrial Cogeneration; Selection of Schemes Optimal Operating Strategies-Peak load saving-Constraints-Problem formulation- Case study; Integrated Load management for Industries;

References:

1 C.O. Bjork, '*Industrial Load Management - Theory, Practice and Simulations'*, Elsevier, the Netherlands, 1989.
2. C.W. Gellings and S.N. Talukdar*, 'Load management concepts'*. IEEE Press, New York, 1986, pp. 3-28.
3. Various Authors, '*Demand side management – Alternatives'*, IEEE Proceedings on DSM , Oct 1985
4. Y. Manichaikul and F.C. Schweppe,'*Physically based Industrial load'*, IEEE Trans. on PAS, April 1981
5. H. G. Stoll*, 'Least cost Electricity Utility Planning'*, Wiley Interscience Publication, USA, 1989.
6. I.J.Nagarath and D.P.Kothari, '*Modern Power System Engineering*', Tata McGraw Hill publishers, New Delhi, 1995.
7. Cogeneration as a means of pollution control and energy efficiency in Asia 2000. Guide book by UNESC for ASIA and the Pacific , Book No: ST/ESCAP/2026, UNESCAP, Bangkok
8. IEEE Bronze Book, '*Recommended Practice for Energy Conservation and cost effective planning in Industrial facilities'*., IEEE Inc, USA.
9. ASHRAE Handbooks, 1997-2000, American Society of Heating, Refrigerating and Air-conditioning Engineers Inc., Atlanta, GA.

10. Richard E. Putman, '*Industrial energy systems: analysis, optimization, and control'*, ASME Press, 2004

EC6104D ELECTROMAGNETIC COMPATIBILITY

Pre-requisites: Nil

L	T	P	C
4	0	0	4

Total hours: 52

Course Outcomes:

CO1: Summarize the importance of electromagnetic compatibility in electronic product design

CO2: Examine different parts of an electronic product for probable EMC failures and propose methods to solve them.

CO3: Choose design techniques to develop EM compatible electronic products.

Module 1: (18 hours)

Need for Electromagnetic Compatibility, Two aspects of EMC – Emission and Susceptibility, Radiation and Conduction, Designing for EMC, EMC regulations, designing for Electromagnetic Compatibility.

Noise and Interference, Typical Noise path, Methods of noise coupling, Non-ideal behavior of electronic components

Capacitive and Inductive Coupling, Effect of Shielding on capacitive and inductive coupling, Shielding to prevent magnetic radiation, shielding a receptor against magnetic fields, Shield Transfer Impedance -shielding properties of various cable configurations, coaxial cable and shielded twisted pair, braided shields, ribbon cables, Shield Terminations

Safety grounds, signal grounds, single point, multi-point and hybrid grounds, Chassis Grounds, Common Impedance Coupling, Grounding of cable shields, Ground loops and its breaking, Common Mode Choke – Analysis at low and high frequencies, Balancing and Filtering

Module 2: (17 hours)

Digital circuit grounding, internal noise sources, Digital circuit ground noise, minimizing ground impedance and loop area, ground grid, ground plane, Ground plane current distribution, ground plane impedance. Current flow in micro-strip and strip-line routing

Digital circuit power distribution- Transient power supply currents, decoupling capacitor design, effective decoupling strategies, decoupling capacitor selection and mounting

Radiated emission - Differential mode and common mode radiation – Reasons and controlling methods,

Conducted emission – Power line impedance, Line impedance stabilization network, Common mode and differential mode noise sources in SMPS. Power line filters,

Module 3: (17 hours)

PCB layout and stack up - General PCB layout Considerations, PCB to chassis ground connections, return path discontinuity, PCB layer stack up, General PCB design procedure, mixed signal PCB layout, Split planes, Ground connection and power distribution, vertical isolation

Near fields and far fields, characteristic and wave impedances, shielding effectiveness, absorption and reflection loss, shielding with magnetic material, apertures, conductive gaskets, conductive windows, conductive coating, grounding of shields.

Electrostatic Discharge (ESD) -Static generation, human body model, static discharge, ESD protection in equipment design, Transient and Surge Protection Devices, ESD grounding, non-grounded products, software and ESD protection, ESD versus EMC, ESD Testing

References:

1. Henry W.Ott, *Electromagnetic Compatibility Engineering*, John Wiley & Sons, 2009
2. Henry W.Ott, *Noise Reduction Techniques in Electronic Systems,* Second Edition Wiley Interscience Publication, 1988

3. Clayton R.Paul, *Introduction to Electromagnetic Compatibility*, Second Edition , Wiley Interscience Publication,2006
4. V. Prasad Kodali, *Engineering Electromagnetic Compatibility-Principles, Measurements, Technologies, and Computer Models* Second Edition IEEE Press, 2001
5. Ralph Morrison*, Grounding and Shielding circuits and interference* 5th edition Wiley,2007

EC6401D LINEAR ALGEBRA FOR SIGNAL PROCESSING

Pre-requisites: Nil

L	T	P	C
4	0	0	4

Total hours: 52

Course Outcomes

CO1: Demonstrate the foundation concepts on Signal Theory and System Theory applicable to Communication Engineering and Signal Processing
CO2: Apply the mathematical framework of Signal Theory and System Theory for Analysis and Design
CO3: Recommend basic concepts that enable designs for environment-friendly direct applications
CO4: Develop ability to think clearly and express precisely, coupled with systematic logical reasoning.

Module 1: (17 hours)

Algebraic Structures:Definitions and properties of Semigroups, Groups, Rings, Fields, and Vector Spaces, Homomorphisms.
Vector Spaces and Linear Transformations: Linear Spaces and Subspaces, and Direct Sums; Linear Independence, Bases, and Dimension; Linear Transformations, Linear Functionals, Bilinear Functionals, and Projections.
Finite-Dimensional Vector Spaces and Matrices:Coordinate representation of vectors, change of basis and change of coordinates; Linear operators, Null space and Range space; Rank-Nullity theorem, Operator inverses, Application to matrix theory, Computation of the range space and null space of a matrix;Matrix of an operator, Operator algebra, change of basis and similar matrices.

Module 2: (18 hours)

Inner Product Spaces:Definition of inner product, norms, angle between vectors**;** Orthogonal sets, Fourier coefficients and Parseval's identity, Gram-Schmidt process, QR factorization; Approximation and orthogonal projection, Computations using orthogonal and non-orthogonal sets, Normal equations; Projection operator, Orthogonal complements, Decomposition of vector spaces, Gram matrix and orthogonal change of basis, Rank of Gram matrix.
Normed Linear Spaces: Metric and metric spaces, Neighborhoods, open and closed sets, Sequences and Series, Continuity and convergence; Norms, Completeness and compactness, Continuous linear transformations, Inverses and Continuous inverses, Complete Normed Linear Space; Norm induced by the Inner product, Hilbert spaces.

Module 3: (17 hours)

Diagonalizable linear operators: Eigenvalues and Eigenvectors, Spectrum and Eigen spaces of an operator, Properties of the characteristic polynomial, Geometric and algebraic multiplicities; Linear operators with an Eigen basis, Diagonalizability and Similarity Transformation; Cayley-Hamilton Theorem, Nilpotent Transformations. Jordan Canonical form.
Quadratic forms: Definition and Properties of quadratic forms; Hermitian forms, Orthogonal Diagonalization and the Principal axis theorem, Simultaneous diagonalization of quadratic forms.
Factorizations: Singular value and Polar Decompositions, The pseudoinverse and the generalized pseudoinverse.

References:

1. Gilbert Strang, "*Introduction to Linear Algebra*," 4th Edition, Wellesley-Cambridge Press, MA, 2009.
2. Kenneth Hoffman, Ray Kunze, "*Linear Algebra*," 2nd Edition, PHI Learning, Delhi, 2014.
3. Anthony N. Michel, Charles J. Herget, "*Applied Algebra and Functional Analysis*," Dover Publications, NY, 1993.
4. Arch W. Naylor, George R. Sell, "*Linear Operator Theory in Engineering and Science*," Springer-Verlag, NY, 2000
5. James M. Ortega, "*Matrix Theory: A Second Course*," Plenum Press/Kluwer Academic, NY, 1987.

EC6434D LINEAR & NONLINEAR OPTIMIZATION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Outline an adequate mathematical background on optimization theory.
CO2: Analyze the basic techniques commonly used in linear programming problems.
CO3: Develop the basic skill to address the nonlinear programming problems.
CO4: Obtain the fundamental knowledge to oversee the constrained and unconstrained optimization problems.

Module 1: (10 hours)

Mathematical background: sequences and subsequences, mapping and functions, continuous functions infimum and supremum of functions minima and maxima of functions, differentiable functions. Vectors and vector spaces, matrices, linear transformation, quadratic forms, gradient and Hessian-Linear equations, solution of a set of linear equations, basic solution and degeneracy, convex sets and convex cones, convex hulls, extreme point, convex and concave functions, differentiable convex functions.

Module 2: (13 hours)

Linear Programming: introduction, optimization model, formulation and applications, classical optimization techniques: single and multi variable problems, types of constraints, graphical method, linear optimization algorithms: simplex method, basic solution and extreme point, degeneracy, primal simplex method, dual linear programs, primal, dual, and duality theory, dual simplex method, primal-dual algorithm. Post optimization problems: sensitivity analysis and parametric programming.

Module 3: (16 hours)

Nonlinear Programming: minimization and maximization of convex functions, local & global optimum, convergence. Unconstrained optimization: one dimensional minimization, elimination methods: Fibonacci & Golden section search, gradient methods. Constrained optimization: Lagrangian method, Kuhn-Tucker optimality conditions, convex programming problems. augmentedLagrangian method (ALM)
Applications of optimization theory in signal processing: signal processing via convex optimization, applications in weight design, linearizing pre-equalization, robust Kalman filtering, online array weight design, basic pursuit denoising (BPDN), compressing sensing and orthogonal matching pursuit (OMP).

References:

1. David G Luenberger, '*Linear and Non Linear Programming*'., Addison-Wesley, 2ndEdn., 2001
2. S.S.Rao, .'*Engineering Optimization.; Theory and Practice*'; John Wiley, 4thEdn.., 2013,
3. S.M. Sinha, '*Mathematical programming: Theory and Methods*', Elsevier, 2006.
4. Hillier and Lieberman '*Introduction to Operations Research*', McGraw-Hill, 8th Ed., 2005.
5. Kalyanmoy Deb, '*Optimization for Engineering: Design Algorithms and Examples*', Prentice Hall, 1998.
6. Igor Griva, ArielaSofer, Stephen G. Nash*: 'Linear and Nonlinear Optimization'*, SIAM, 2009.

NS6101D STRUCTURE OF NANOMATERIALS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Appraise the nanoscale effects in material performances.
CO2: Analyze the physics of nanoscale effects shown by materials.
CO3: Examine the structure – property correlations of nanomaterials.
CO4: Design of nano structured and fine grained materials.

Module 1: (10 hours)

Introduction to nanomaterials: history, scope and applications of nanomaterials, small things making big differences, nanotechnology as nature's technology, clusters and magic numbers, classification of nanomaterials, nanoscale architecture. Recent developments, challenges and future prospects of nanomaterials.

Module 2: (10 hours)

Physics of nanomaterials: 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, anisotropy, periodic potential, confinement, quantization, , exciton, confining the exciton, quantum well, quantum wire and quantum dot.

Module 3: (10 hours)

Microstructure and defects in nanocrystalline materials: grain size distributions and morphology, grain boundaries, triple junctions and interfaces, dislocations, twins, stacking faults.
Effect of nano dimensions on materials behaviours: elastic properties, melting point, diffusivity, grain growth, solid solubility, magnetic properties, electrical properties, optical properties, thermal properties, mechanical properties.

Module 4: (9 hours)

Nanocrystalline materials, nanocomposites, bulk metallic glasses, ultrafine grain materials, severe plastic deformation techniques, mechanical alloying, rapid solidification process, surface nano featuring of materials.

References:

1. Murty, B. S., P. Shankar, Baldev Raj, B. B. Rath, and James Murday. '*Textbook of nanoscience and nanotechnology*'. Springer Science & Business Media, 2013.
2. Pradeep, T. '*A textbook of nanoscience and nanotechnology*'. Tata McGraw-Hill Education, 2012.
3. Prathap, Haridoss.,'*Physics of materials: Essential Concepts of Solid – State Physics*', Wiley India Pvt. Ltd., 2016.
4. Yannick Champion , Hans-JörgFecht, '*Nano-Architectured and Nanostructured Materials: Fabrication, Control and Properties*', Wiley-VCH,2005.
5. Robert K, Ian H, Mark G, '*Nanoscale Science and Technology*', John Wiley & sons Ltd.,2005.

NS6111D SPECTROSCOPIC CHARACTERISATION OF NANOMATERIALS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Apply the concepts and principles of spectroscopic methods for characterization of Nanomaterials.
CO2: Interpret the analytical information for the comprehensive characterization of nanomaterials.
CO3: Assess the suitable technique for the apt evaluation of nanomaterials.
CO4: Appraise the electrochemical methods to comprehend the nanomaterial.

Module1: (11 hours)

Surface analytical techniques, Surface sensitivity, Basics of spectroscopy, Infrared spectroscopy (IR), Functional groups, Attenuated total internal reflection IR, Diffuse reflectance and specular reflectance, *Surface enhanced infrared absorption* spectroscopy , Raman Spectroscopy, resonance Raman, surface enhanced Raman and surface enhanced resonance Raman spectroscopy, Tip enhanced Raman spectroscopy, Confocal Raman microscopy, Analysis of nanomaterials using IR, Raman spectroscopy.

Module2: (11 hours)

UV-Visible absorption spectroscopy, Principle and application in nanomaterials, Metal nanoparticles and semiconductor nanoparticles, Diffuse reflectance, Calculation of band gaps from diffuse reflectance spectroscopy, Fluorescence spectroscopy, Photoluminescence of nanomaterials, Photoelectron spectroscopy, Ultraviolet photoelectron spectroscopy and X-ray photoelectron spectroscopy, Principle and analysis of spectra, X-ray Fluorescence, Auger electron spectroscopy, Electron energy loss spectroscopy.

Module3: (6 hours)

Mass spectrometry techniques -Basics and application in nanomaterials, Tandem Mass, Matrix Assisted Laser Desorption/Ionisation, Secondary ion mass spectrometry, Electron spray ionization, Analysis of clusters using mass spectrometry.

Module4: (11 hours)

An overview of electrochemistry, Electrochemistry in materials science, Principles of electrochemistry, Dynamic electrochemistry: Processes at electrodes, Electrochemical instrumentation and techniques, Cyclic voltammetry, Differential pulse voltammetry, Square wave voltammetry, Impedance spectroscopy, Electrochemical quartz crystal microbalance, Electro chemiluminescence, spectroelectrochemistry, Optical probing of electrode-solution interfaces.

References:

1. J. O'Connor, B. Sexton, R. Smart, '*Surface Analysis Methods in Materials Science'*, Springer, 2003.
2. Helmut Gunzler and Alex Williams, '*Handbook of Analytical Techniques'*, Wiley-VCH, 2002.
3. C. Banwell and E. Mccash, '*Fundamentals of molecular spectroscopy'*, McGraw Hill, 1994.
4. G. Hodes, '*Electrochemistry of Nanomaterials'*, Wiley-VCH, 2001.
5. D.P. Woodruff, '*Modern Techniques of Surface Science'*, Cambridge University Press, 2016

NS6112D EXPERIMENTAL TECHNIQUES IN NANOTECHNOLOGY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Apply the concepts and principles of microscopic methods for characterization of Nanomaterials.
CO2: Interpret the analytical information for the comprehensive characterization of nanomaterials.
CO3: Assess the suitable technique for the apt evaluation of nanomaterials.
CO4: Appraise the thermal analysis used in nanomaterial characterizations.

Module 1: (9 hours)

Design of Experiments - Best guess approach-One factor- at - time approach- Factorial approach- Elementary ideas of blocking, randomization, replication – Errors – Uncertainty analysis. Material characterization techniques –BET surface area analysis - Differential Scanning Calorimeter (DSC), Differential Thermal Analyzer (DTA), Thermo Gravimetric Analysis (TGA) - Dynamic mechanical analysis (DMA)-Temperature programme reduction.

Module 2: (10 hours)

Intrusive and non-intrusive temperature measurement techniques, Infrared thermography, Thermo reflectance thermography, Liquid crystal thermography.Interferometry, Moir’e interferometry- Electronic speckle pattern interferometry- Deformations in nanostructures Measurement of properties of Nanofluids -thermal conductivity - steady state and transient methods- viscosity- Broke field viscometer. Stability of nano fluids- Particle size distribution - Zeta potential - Dynamic light scattering system- Acoustic-Attenuation spectroscopy, Photo acoustic spectroscopy, Surface energy analysis.

Module 3: (10hours)

Characterization techniques in nanotechnology – Electron Microscopy - instrumentation and application, Sample preparation techniques - contrast mechanisms - Scanning electron microscopy, Transmission electron microscopy and HRTEM, SAED, EELS, Electron back scattering (EBSD) - X-ray micro analysis (EDS, WDS).

Module 4: (10 hours)

Scanning probe microscopy, tapping mode, contact mode, MFM, EFM, I-AFM, DC-AFM, PFM, FMM, LFM, SCM, SThM, SKM, F-d spectroscopy, Nanoindentation, Nanoscratching, Scanning tunneling microscopy, Scanning near field microscopy (SNOM), XRD.

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. David B. Williams, C. Barry Carter, ‘*Transmission Electron Microscopy’*, Springer 2009.
4. Nan Yaho and Zhong, ‘*Hand book of Microscopy for Nanotechnology’*, Kluwer Academic press, Boston, 2005.
5. K.S Birdi, *Scanning Probe Microscopy*, CRC Press, 2003.
6. C B Sobhan, G P Peterson, ‘*Microscale and Nanoscale Heat Transfer-Fundamentals and Engineering Applications’*, Taylor and Francis/CRC, 2008.
7. Ernest O Doeblin., "*Measurement Systems: Application and Design*", McGraw Hill (Int. Edition) 1990.
8. MIcheal E Brown, ‘*Introduction to Thermal Analysis, Techniques and applications’*, Kluwer Academic Publishers 2001

NS6122D NANOMATERIALS FOR ENERGY AND ENVIRONMENT

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Apply the concepts and principles of conversion and storage of renewable energy sources.
CO2: Evaluate the efficiency of nanocatalysts for electrochemical energy generation and storage.
CO3: Design the suitable nanomaterials for environmental remediation.
CO4: Analyze the toxicity of nanomaterials.

Module1: (10 hours)

Energy and Environment, sustainable energy production based on renewable energy sources, Sustainability: Agriculture, Water, Energy, Materials and clean environment, Nanomaterials used in energy and environmental applications and their properties**,** Solar energy,solar cells, dye sensitized solar cell, organic solar cells, Hydrogen energy, hydrogen production by water splitting, hydrogen storage.

Module2: (12 hours)

Alternative energy technologies, Electrochemical energy conversion and storage systems, Fuel cells, Types of fuel cells, thermodynamics of fuel cells, electrocatalysts for anode reactions, catalysts for oxygen reduction reactions, Batteries, Li-ion battery, Na-ion battery, General properties of electrochemical capacitors, Supercapacitor, Electrical double layer capacitor, pseudocapacitor, Li-ion based hybrid supercapacitors, Applications of electrochemical capacitors.

Module3: (10 hours)

Green nanotechnology and its principles, Nanomaterials for environmental Remediation, Photocatalysis, Water purification using nanomaterials, desalination of water, Solid waste removal, Porous materials to store clear energy gases, Metal organic frame works(MOFs), Storage of carbon dioxide, methane and hydrogen in MOFs.

Module4: (7 hours)

Potential impacts of nanomaterials on organisms and ecosystems, Nanotoxicology, Introduction to nanomaterial toxicity, environmental and health impacts, Biomagnification, Nanoparticles exposure assessment, toxicity of inhaled nanomaterials, Basics of toxicity studies, Cytotoxicity induced by nanomaterials, ethical, legal, and societal implications of nanotechnology.

References:

1. Jingbiolouise Liu, Sajid Bashir, '*Advanced Nanomaterials and their applications in Renewable energy'*, Elsevier, 2015.
2. Tetsuo Soga, '*Nanostructured Materials for Solar Energy Conversion'*, Elsevier , 2006.
3. G.A. Nazri and G. Pistoia, '*Lithium Batteries: Science and Technology'*, Kluwer Academic Publishers, Dordrecht, Netherlands, 2004.
4. J. Larmine and A. Dicks, '*Fuel Cell System Explained'*, John Wiley, New York , 2000.
5. Francois B´eguin and El˙zbietaFrackowiak, '*Supercapacitors'*, Wiley-VCH, 2013.
6. Challa S.S.R. Kumar, '*Nanomaterials:toxicity, health and environmental issues'*, Wiley-VCH, 2006.

NS6124D COMPUTATIONAL NANOTECHNOLOGY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Develop computational simulation methodologies and discuss their applications.
CO2: Assess the application statistical mechanics and theorems involved.
CO3: Analyze physical problems with the help of atomistic simulation techniques.
CO2: Analyze problems using mesoscopic simulation techniques.

Module 1:(10 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:(9 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, time step 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.