CURRICULUM AND SYLLABI

M.Tech.

in

POWER ELECTRONICS

(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 POWER ELECTRONICS

PEO 1	To equip the engineering graduates with enhanced knowledge and skills in the area of Power Electronics so as to excel in various sectors in modern power industry/utility and/ or teaching and/or higher education and / or research.
PEO 2	To transform engineering graduates to expert Power Electronic engineers so that they could comprehend, analyze, design and create novel products and solutions to problems in the area of Power Electronics that are technically sound, economically feasible and socially acceptable.
PEO 3	To train engineering graduates to exhibit professionalism, keep up ethics in their profession and relate engineering issues to address the technical and social challenges
PEO 4	To improve the communication skills, willingness to work in groups and to develop multidisciplinary approach in problem solving

The Programme Outcomes (POs) of
M. Tech.Programme in POWER ELECTRONICS

PO1	An ability to independently carry out research/ investigation and development work to solve practical problems.
PO2	An 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	An ability to provide engineering solutions to the problems pertaining to Power Electronics by utilizing the acquired knowledge and to take up project management issues including financial and administrative challenges in the power electronics space, having multidisciplinary nature.
PO5	Willingness and ability for the sustentation of professional ethics and social values while carrying out the responsibilities as a Power Electronics engineer/researcher in devising solutions to real life engineering problems in an independent manner, with a perspective to sustained lifelong learning process.

Curriculum for M. Tech. Programme in Power Electronics

This Programme is offered in four semesters. The structure of the programme shall be the following:

Semester 1

Course Code	Course Title	L	T	P/S	C
MA6003D	Mathematical Methods for Power Engineering	3	0	-	3
EE6301D	Power Electronic Circuits	3	0	-	3
EE6303D	Dynamics of Electrical Machines	3	0	-	3
	Elective -1	3	0	-	3
	Elective -2	3	0	-	3
EE6391D	Power Electronics Lab	-	-	2	1
EE6393D	Seminar	-	-	2	1
Total					17

Semester 2

Course Code	Course Title	L	T	P/S	C
EE6302D	Advanced Power Electronic Circuits	3	0	-	3
EE6304D	Modern Digital Signal Processors	3	0	-	3
EE6306D	Power Electronic Drives	3	0	-	3
EE6308D	Switched Mode & Resonant Converters	3	0	-	3
	Elective -1	3	0	-	3
	Elective - 2	3	0	-	3
EE6392D	Mini Project / Industrial training	-	-	2	1
Total					19

Semester 3

Course Code	Course Title	L	T	P/S	C
EE7391D	Project – Part 1	-	-	20	10
Total				20	10

Semester 4

Course Code	Course Title	L	T	P/S	C
EE7392D	Project –Part 2	-	-	28	14
Total				28	14

LIST OF ELECTIVES

Sl. No	Code	Title	Credits
1	EE6321D	Power Semiconductor Devices and Modelling	3
2	EE6322D	Static VAR Controllers and Harmonic Filtering	3
3	EE6323D	Digital Simulation of Power Electronic Systems	3
4	EE6324D	Advanced Control of Inverter-fed Induction Motor Drives	3
5	EE6325D	Linear and Digital Electronics	3
6	EE6327D	Implementation of DSP Algorithms	3
7	EE6329D	Advanced Microprocessor Based Systems	3
8	EE6101D	Systems Theory	3
9	EE6103D	Measurements and Instrumentation	3
10	EE6105D	Digital Control: Theory and Design	3
11	EE6102D	Optimal and Robust Control	3
12	EE6104D	Advanced Instrumentation	3
13	EE6106D	Stochastic Modelling and Identification of Dynamical Systems	3
14	EE6108D	Nonlinear Systems and Control	3
12	EE6121D	Data Acquisition and Signal Conditioning	3
13	EE6125D	Adaptive Control Theory	3
14	EE6126D	Advanced Topics in Control Systems	3
15	EE6127D	Optimal Estimation and Filtering	3
16	EE6128D	Variable Structure Control Systems	3
17	EE6130D	Quantitative Feedback Theory	3
18	EE6132D	Numerical Methods for Control System Design	3

19	EE6134D	Networked Control and Multiagent Systems	3
20	EE6135D	Flexible Structures	3
21	EE6138D	Selected Topics in Control	3
22	EE6140D	Advanced Soft Computing Techniques	3
23	EE6201D	Computer Methods in Power System Analysis	3
24	EE6202D	Power System Dynamics and Control	3
25	EE6203D	Distributed Generation & Microgrid	3
26	EE6204D	FACTS and Custom Power	3
27	EE6221D	Power Quality Issues and Remedial Measures	3
28	EE6224D	Distributed Processing of Power Systems	3
29	EE6226D	Hybrid and Electric Vehicles	3
30	EE6401D	Energy Auditing & Management	3
31	EE6402D	Process Control and Automation	3
32	EE6403D	Computer Controlled Systems	3
33	EE6404D	Industrial Instrumentation	3
34	EE6405D	Artificial Intelligence & Automation	3
35	EE6421D	Smart Grid Technologies and Applications	3
36	EE6422D	Engineering Optimization and Algorithms	3
37	EE6424D	Robotic Systems and Applications	3
38	EE6426D	Distribution systems Management and Automation	3
39	EE6428D	SCADA Systems & Applications	3
40	EE6430D	Network & Data Security	3
41	EE6432D	Advanced Algorithms & Data Structure Analysis	3
42	EE6434D	Internet of Things and Applications	3
43	EE6436D	Industrial Load Modeling & Control	3
44	EE6521D	HVDC transmission	3
45	EE6523D	Condition Monitoring of Power Equipment	3
46	EE6524D	Electromagnetic Interference and Compatibility	3
47	EE6525D	Pulsed Power Engineering	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 (10 hours)

Mathematical formulation of Linear Programming Problems, Simplex Method, Duality in Linear Programming, Dual Simplex method.

Module 3: Optimisation Methods II (10 hours)

Non Linear Programming preliminaries, Unconstrained Problems, Search methods, Fibonacci Search, Golden Section Search, Constrained Problems, Lagrange method, Kuhn-Tucker conditions

Module 4: Operations on Random Variables (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.

Text Books and References:

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

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 .

Textbooks and 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)., 2007,09

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

EE6303D DYNAMICS OF ELECTRICAL MACHINES

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:

CO1: Formulate electrodynamic equations for the electrical machines.
CO2: Analyse the performance of the electrical machines using the electrodynamic equations.
CO3: Develop power invariant transformations for the dynamic analysis of electrical machines.
CO4: Carryout Stability analysis of the electrical machines under small signal and transient conditions.

Module 1: (12 hours)

Electrodynamic equations and their solution - a spring and plunger system - rotational motion system - mutually coupled coils - lagrange's equation - application of lagrange's equation to electromechanical systems - solution of electrodynamic equations by euler's and runge-kutta methods - linearisation of the dynamic equations and the small signal stability - differential equations and solutions - a smooth air-gap two winding machine - a two phase machine with current excitation - interpretation of the average power conversion conditions in terms of air-gap magnetic fields - primitive 4 winding commutator machine - commutator primitive machine - brush axis and its significance - self and mutually induced voltages in the stationary and commutator windings - speed emf induced in commutator winding - rotational inductance coefficients - sign of speed emf terms in the voltage equation - complete voltage equation of primitive 4 winding commutator machine - torque equation - analysis of dc machine using the primitive machine equations.

Module 2: (9 hours)

Three phase induction motor - equivalent two phase machine by mmf equivalence - equivalent two phase machine currents from three phase machine currents - power invariant phase transformation - voltage transformation - voltage and torque equations of the equivalent two phase machine - commutator transformation and its interpretation - transformed equations - different reference frames for induction motor analysis - nonlinearities in machine equations - equations under steady state - linearised equations of induction machine - small signal and transient stability analysis - eigen values - transfer function formulation.

Module 3: (9 hours)

Three phase salient pole synchronous machine - three phase to two phase transformation - voltage and torque equations in various reference frames - commutator transformation and transformed equations - parks transformation - suitability of reference frame - steady state analysis - large signal transient analysis - eigen values - general equations for small oscillations - small oscillation equations in state variable form - damping and synchronizing torques - small oscillation stability analysis - application of small oscillation models in power system dynamics.

Module 4: (9 hours)

Dynamic analysis of interconnected machines - machine interconnection matrices - transformation of voltage and torque equations using interconnection matrices - large signal transient analysis using transformed equations - small signal model using transformed equations - dc generator-motor system - synchronous generator-motor system -ward-leonard system - hunting analysis of interconnected machines - selection of proper reference frame for individual machines in an interconnected system.

References:

1. D P Sengupta & J.B. Lynn, '*Electrical Machine Dynamics*', The Macmillan Press Ltd. 1980.
2. R Krishnan, '*Electric Motor Drives, Modeling, Analysis and Control*', Pearson Education, 2001.

3. P.C. Kraus, '*Analysis of Electrical Machines'*, McGraw Hill Book Company,1987.
4. I. Boldia & S A Nasar, '*Electrical Machine Dynamics'*, The Macmillan Press Ltd. 1992.
5. C.V. Jones, '*The Unified Theory of Electrical Machines'*, Butterworth, London. 1967.

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 - C C 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. Naim Dahnoun '*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 Hulley Cambride,'*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

EE6308D SWITCHED MODE & RESONANT CONVERTERS

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the principles of operation of non-isolated and isolated hard-switched DC-DC converters

CO2: Illustrate various loss components in a switched mode converter and choice of switching frequency with a view towards design of such converters

CO3: Demonstrate the magnetics in switched mode converters and design of high frequency inductors and transformers with a DC bias.

CO4: Design voltage mode and current mode control of DC-DC converters and familiarization with various controller ICs available in the market.

CO5 Develop large-signal model and small signal model of hard-switched converters, develop the transfer functions and design error amplifiers in the feedback loop.

CO6: Analyse the transients and their control in hard-switched converters by use of proper wiring practices, judicious component selection and various snubbers.

Module 1:**(13 hours)**

Buck, Boost, Buck-Boost SMPS Topologies . Basic Operation- Waveforms - modes of operation - switching stresses - switching and conduction losses - optimum switching frequency - practical voltage, current and power limits - design relations - voltage mode control principles.

Push-Pull and Forward Converter Topologies - Basic Operation . Waveforms - Flux Imbalance Problem and Solutions - Transformer Design -Output Filter Design -Switching Stresses and Losses – Forward Converter Magnetics --Voltage Mode Control.

Half and Full Bridge Converters . Basic Operation and Waveforms-Magnetics . Output Filter . Flux Imbalance . Switching Stresses and Losses . Power Limits . Voltage Mode Control. Flyback Converter .discontinuous mode operation . waveform. Control . Magnetics- Switching Stresses and Losses . Disadvantages - Continuous Mode Operation .Waveforms, Control . Design Relations

Module 2: **(13 hours)**

Voltage Mode Control of SMPS . Loop Gain and Stability Considerations . Shaping the Error Amp frequency Response . Error Amp Transfer Function .Transconductance Error Amps . Study of popular PWM Control Ics (SG 3525,TL 494,MC34060 etc.)

Current Mode Control of SMPS . Current Mode Control Advantages . Current Mode Vs Voltage Mode .Current Mode Deficiencies . Slope Compensation . Study of a typical Current Mode PWM Control IC - UC3842.

One cycle control in SMPS.

Linear Assisted Hybrid SMPS topology and control.

Module 3: **(13 hours)**

Modeling of SMPS . State Space Averaging and Linearisation . State Space Averaging Approximation for Continuity . Discontinuous Conduction Modes . Small Signal Approximation- General Second Order Linear Equivalent Circuits . The DC Transformer . Voltage Mode SMPS Transfer Function . General Control Law Considerations . Source to State Transfer Function . Source to Output Transfer Function .Stability . Loop Compensation

EMI Generation and Filtering in SMPS - Conducted and Radiated Emission Mechanisms in SMPS . Techniques to reduce Emissions . Control of Switching Loci . Shielding and Grounding . Power Circuit Layout for minimum EMI . EMI Filtering at Input and Output . Effect of EMI Filter on SMPS Control Dynamics

Text Books and References:

1. Abraham I Pressman ,"*Switching Power Supply Design*". McGraw Hill Publishing Company,2001.
2 Daniel M Mitchell, "*DC-DC Switching Regulator Analysis*", McGraw Hill Publishing Company-1988
3. Ned Mohan, *Power Electronics*.,John Wiley and Sons 2006
4. Otmar Kilgenstein, "*Switched Mode Power Supplies in Practice*", John Wiley and Sons,1994.
5. Keith H Billings "*Handbook of Switched Mode Power Supplies*", McGraw Hill Publishing Company,1989.
6. Mark J Nave, "*Power Line Filter Design for Switched-Mode Power Supplies*", VanNostrand Reinhold, New York, 1991

EE6391D POWER ELECTRONICS LAB

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:

CO1: Develop the skill to Design and simulate Power Electronic Circuits.
CO2: Analyze simulation results and do effective documentation.
CO3: Design and implement hardware for power electronic systems.
CO4: Construct modern power electronic hardware and use software tools to support it.

List of Experiments

1. MOSFET Characteristics
2. IGBT Characteristics
3. Fullwave Uncontrolled Rectifier With C-Filter, L-Filter, L-C Filter
4. Fullwave Uncontrolled Rectifier With Voltage Doublers
5. Fullwave Controlled Rectifier With C-Filter, L-Filter, L-C Filter
6. Chopper Design and Implementation
7. H-Bridge inverter design and Implementation

EE6393D SEMINAR

Pre-requisites: Nil

L	T	P	C
0	0	3	1

Course outcomes:

CO1: Study the recent and old research papers for understanding of an emerging technologies in the field of power electronics, in the absence of a text book. Summarize the objective the paper and review the effectiveness

CO2: Identify promising new directions of various cutting edge technologies

CO3: Impart skills in preparing a detailed report describing the reviewed topic

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

Individual students will be asked to choose a topic in any field of Power Electronics, preferably from outside the M.Tech syllabus and give seminar on the topic for a bout thirty minutes. A committee consisting of at least three faculty members specialized on different fields of engineering 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.

EE6392D MINI PROJECT / INDUSTRIAL TRAINING

Pre requisites: Nil

L	T	P	C
0	0	3	1

Course outcomes:
MINI PROJECT:

CO1: Undertake individual mini research projects in the area of power electronics under the guidance of a regular faculty

CO2: Develop a complete small design and implement the projects in a hardware prototype/experimental setup and obtain the experimental results.

CO3: Formulate detailed design reports describing the relevance of the project, modelling aspects, methodologies and analysis of the results.

CO4: Communicate appropriately by making an oral presentation.

INDUSTRIAL TRAINING:

CO1: Understand the vibrant atmosphere prevailing in an industry/project site.

CO2: Explain different processes in Industry.

CO3: Identify the roles of the management & administrative, non-technical operations/divisions in an industry.

CO4: Recognize issues/problems in the industry and suggest improvements/solutions.

CO5: Adapt with the etiquette/mannerism/self-discipline followed by professionals.

CO6: Develop the skill to manage people in an industry.

The mini project can be analytical / simulation/design or and fabrication in any of the areas in Power Electronics. Project must be done by individual student under any faculty of the Electrical Engineering Department as the guide. A faculty coordinator will coordinate project work of all students. The mini project is usually allotted by the Dept 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 nominated by the HOD. The faculty coordinator of the project will be a member of the evaluation committee 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.

Industrial Training shall be completed during summer vacation and will be credited in 3rd semester along with major project -1

Minimum Duration of the industrial training shall be 20 days in a reputed industry**.** Training should be focussed on the familiarization with the dynamic environment in an industry to identify issues/problems and suggest improvements/solutions.

Course Assessment Methods:
Students will select a reputed industry for the training from the approved list of industries. During the training, students shall make a detailed study of the plant/process, identify a specified area/process which needs improvements, he/she shall go in detail in the selected process with hands on experience, identify the problems and solutions for improvements, discuss with the plant engineers/officials, if possible, implement the suggested solution /improvement, conclude and report to plant manager. A certificate from the plant officials shall be enclosed with the report.

Evaluation : 100 marks
(Understanding the plant process, Problem identification, Solution strategies, Suggestions from plant officials, Implementation steps: 70 marks
Presentation, results, report, outcome: 30 marks)

EE7391D PROJECT – PART 1

Pre-requisites: Nil

L	T	P	C
0	0	16	8

Course outcomes:

CO1: Research, Design, and implement power electronic circuits / Systems.
CO2: Able to identify a topic of interest and complete the preliminary work of undertaking case studies, data collection and feasibility studies.
CO3: Explain how to formulate and develop a design proposal and to effectively document the same.
CO4: Effectively communicate by making an oral presentation of the progress of work.

The project work will be a design project / experimental project in the areas of Power Electronics. 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 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.

EE7392D PROJECT –PART 2

Pre requisites: EE7391D PROJECT – PART 1

L	T	P	C
0	0	24	12

Course outcomes:

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

CO2: Synthesize the results of the detailed analytical studies conducted, lay down validity and design criteria, interpret the result for application to the power electronic design problems.

CO3: Report the concept and detailed design solutions and effectively communicate the thesis rationale and publish in reputed journals/conference.

The project work is evaluated in two stages. The first stage assessment of the project will be done at the end of third semester and the final stage assessment at the end of fourth semester. Evaluation will be done by a committee consisting of the concerned guide and two/three faculty members in the concerned area of the project nominated by the Programme Coordinator. The program Coordinator of the M.Tech Stream will be a member of the evaluation committee of 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. The Department level evaluation shall have 70% weight in the final grading of which 50% weight will be given to the assessment by the individual guide. Remaining 30% marks is awarded in the external evaluation with an external examiner nominated by the Program Coordinator and approved by the HoD. Final marks will be reported based on 100 as maximum.

EE6321D POWER SEMICONDUCTOR DEVICES AND MODELING

Pre-requisite: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course outcomes:
CO1: Explain the basics of power semiconductor switches.
CO2: Illustrate the working of various types of converters and application of them.
CO3: Design the drive circuits for various Power Semiconductor Switches.
CO4: Model the converters and semiconductor switches.
CO5: Design the control of various power semiconductor switches.

Module 1: (10 hours)

Power Diodes. Basic Structure and I-V Characteristics. Breakdown Voltages and Control. On State Losses. Switching Characteristics. Turn on Transient . Turn off Transient . Reverse Recovery Transient . Schottky Diodes .Snubber Requirements for Diodes and Diode Snubbers. Thyristors - Basic Structure . V-I Characteristics . Turn on Process . On State operation . Turn off process

.Switching Characteristics .Turn on Transient and di/dt limitations . Turn off Transient . Turn off time and reapplied dv/dt limitations. Ratings of Thyristors. Snubber Requirements and Snubber Design. Triacs . Basic Structure and operation . V-I Characteristics .Ratings . Snubber Requirements.

Gate Turnoff Thyristor (GTO). Basic Structure and Operation. GTO Switching Characteristics. GTO Turn on Transient . GTO Turn off Transient. Minimum ON and OFF State times .Maximum Controllable Anode Current. Over current protection of GTOs

Module 2:**(13 hours)**

Power BJTs . Basic Structure and I-V Characteristics. Breakdown Voltages and Control .

Second Breakdown and its Control- FBSOA and RBSOA Curves - On State Losses . Switching

Characteristics.

Resistive Switching Specifications. Clamped Inductive Switching Specifications. Turn on Transient. Turnoff Transient . Storage Time .Base Drive Requirements . Switching Losses . Device Protection-Snubber. Requirements for BJTs and Snubber Design - Switching Aids.

Power MOSFETs - Basic Structure . V-I Characteristics . Turn on Process . On State operation . Turn off process . Switching Characteristics . Resistive Switching Specifications . Clamped Inductive Switching Specifications - Turn on Transient and di/dt limitations . Turn off Transient . Turn off time . Switching Losses . Effect of Reverse Recovery Transients on Switching Stresses and Losses - dv/dt limitations .

Gating Requirements . Gate Charge - Ratings of MOSFETs. FBSOA and RBSOA Curves . Device Protection –Snubber Requirements .

Insulated Gate Bipolar Transistors (IGBTs) . Basic Structure and Operation .Latch up IGBT Switching Characteristics . Resistive Switching Specifications . Clamped Inductive Switching Specifications – IGBT Turn on Transient. IGBT Turn off Transient- Current Tailing - Ratings of MOSFETs. FBSOA and RBSOA Curves . Switching Losses - Minimum ON and OFF State times - Switching Frequency Capability – Over current protection of IGBT. Short Circuit Protection .Snubber Requirements and Snubber Design.

Module 3: **(7 hours)**

New power semiconductor devices . Thermal design of power electronic equipment .Modelling of power semiconductors (principles). Simulation tools

Module 4: **(9 hours)**

Gating Requirements for Thyristor, Component Temperature Control and Heat Sinks . Control of device temperature .heat transfer by conduction. transient thermal impedance - heat sinks .heat transfer by radiation and convection - Heat Sink Selection for SCRs and GTOs.

Modelling of power diode - Modelling of power MOSFET - Modelling of bipolar transistor - Modelling of IGBT

Text Books and References:

1. Ned Mohan, "*Power Electronics*",John Wiley and Sons,2006
2. G. Massobrio, P. Antognet," *Semiconductor Device Modeling with Spice*", McGraw-Hill, Inc.,1988.
3. B. J. Baliga," *Power Semiconductor Devices*",Thomson, 2004.
4. V. Benda, J. Gowar, D. A. Grant," *Power Semiconductor Devices. Theory and Applications*", John Wiley & Sons1994.99

EE6322D STATIC VAR CONTROLLERS AND HARMONIC FILTERING

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours : 39

Course outcomes:

CO1: Explain the fundamental principles of Passive and Active Reactive Power Compensation Schemes at Transmission and Distribution level in Power Systems.
CO2: Illustrate various single phase and three-phase Static VAr Compensation Schemes and their controls
CO3: Develop models of Static VAr systems with a view towards Controller Design
CO4: Demonstrate the fundamental principles of Passive and Active Harmonic Filtering in Power Systems.
CO5: Analyse various single-phase and three-phase active harmonic filtering systems employing Current-regulated PWM VSI and their control.
CO6: Analyse and Model Active Harmonic Filtering systems with a vision towards Controller Design.

Module 1 : (10 hours)

Fundamentals of Load Compensation , Steady-State Reactive Power Control in Electric Transmission Systems , Reactive Power Compensation and Dynamic Performance of Transmission Systems . Power Qulity Issues. Sags, Sweels, Unbalance, Flicker, Distortion , Current Harmonics - Sources of Harmonics in Distribution Systems and Ill Effects .

Module 2: **(10 hours)**

Static Reactive Power Compensators and their control . Shunt Compensators, SVCs of Thyristor Switched and Thyristor Controlled types and their control, STATCOMs and their control, Series Compensators of Thyristor Switched and Controlled Type and their Control, SSSC and its Control, Sub-Synchronous Resonance and damping, Use of STATCOMs and SSSCs for Transient and Dynamic Stability Improvement in Power Systems.

Module 3: **(10 hours)**

Converters for Static Compensation . Single Phase and Three Phase Converters and Standard Modulation Strategies (Programmed Harmonic Elimination and SPWM) . GTO Inverters . Multi-Pulse Converters and Interface Magnetics . Multi-Level Inverters of Diode Clamped Type and Flying Capacitor Type and suitable modulation strategies (includes SVM) . Multi-level inverters of Cascade Type and their modulation. Current Control of Inverters.

Module 4: **(9 hours)**

Passive Harmonic Filtering . Single Phase Shunt Current Injection Type Filter and its Control, Three Phase Three-wire Shunt Active Filtering and their control using p-q theory and d-q modelling . Three-phase four wire shunt active filters . Hybrid Filtering using Shunt Active Filters . Series Active Filtering in Harmonic Cancellation Mode . Series Active Filtering in Harmonic Isolation Mode . Dynamic Voltage Restorer and its control . Power Quality Conditioner

Text Books and References:

1. T.J.E Miller. '*Reactive Power Control in Electric Systems'*, John Wiley & Sons,1982.
2. N.G. Hingorani & L. Gyugyi '*Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems'*. IEEE Press, 2000.
3. Ned Mohan. '*Power Electronics'*. John Wiley and Sons 2006

EE6323 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 MicroSim PSpice A/D - Simulation Overview - Creating and Preparing a Circuit for Simulation - Simulating a Circuit with PSpice A/D - Displaying Simulation Results - PSpice A/D Analyses - Simple Multi-run Analyses - Statistical Analyses - Simulation Examples of Power Electronic systems.

Module 3: PSpice and MATLAB (9 Hours)

MicroSim PSpice A/D - Preparing a Schematic for Simulation - Creating Symbols - Creating - Models - Analog Behavioral Modeling - Setting Up and Running analyses - Viewing Results - Examples of 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.

EE6324D ADVANCED CONTROL OF INVERTER-FED INDUCTION MOTOR DRIVES

Pre-requisite: Nil

L	T	P	C
3	1	0	3

Total Hours: 39

Course outcomes:

CO1: Illustrate the dynamic model of induction machines for different frames of reference.
CO2: Design field oriented (vector) control system of induction machines.
CO3: Analyze the effects of machine parameter variations on the performance of induction machine fed drives.
CO4: Explain the sensor-less speed control methods of induction machines.
CO5: Design a vector controlled induction machine drive system

Module 1:**(12 hours)**

Principles for vector and field-oriented control**-**Complex-valued dq-model of induction machines. Turns ratio and modified dq-models. Principles for field-oriented vector control of ac machines. Current controllers in stationary and synchronous coordinates. Rotor-flux oriented control of current-regulated induction machine - Dynamic model of IM in rotor-flux coordinates. Indirect rotor-flux oriented control of IM - Direct rotor-flux oriented control of IM.-Methods to estimation of rotor-flux

Module 2: **(9 hours)**

Generalized flux-vector control using current- and voltage decoupling networks**-** Generalized flux-vector oriented control. Current and voltage decoupling networks. Air gap-oriented control. Voltage-fed vector control. Stator-flux oriented vector control.

Module 3: **(9 hours)**

Parameter sensitivity, selection of flux level, and field weakening - Parameter detuning in steady-state operation. Parameter detuning during dynamics. Selection of flux level. Control strategies for used in the over-speed region .

Module 4: **(9 hours)**

Principles for speed sensor-less control **-** Principles for speed sensor-less control. Sensor-less methods for scalar control. Sensor-less methods for vector control .Introduction to observer-based techniques

Textbooks and References:

1. Extract of D. W. Novotny and T. A. Lipo, '*Vector Control and Dynamics of AC Drives'*, Oxford University Press,1996.
2. P. L. Jansen and R. D. Lorenz, '*A Physically Insightful Approach to the Design and Accuracy Assessment of Flux Observers for Field Oriented Induction Machine Drives'*, IEEE Trans. on Industry Applications, Vol. 30, No. 1, Jan./Feb. 1994, pp. 101110
3. Extract of I. Boldea and S. A. Nasar. '*Electric Drives'*, CRC Press, 1998.
4. J. Holtz, '*Methods for Speed Sensor less Control of AC Drives'*, in K. Raja shekara Sensor less Control of AC motors. IEEE Press Book, 1996. Supplementary literature
5. R. W. De Doncker and D. W. Novotny, *'The Universal Field Oriented Controller'*, IEEE Trans. on Industry Applications, Vol. 30, No. 1, Jan./Feb. 1994, pp. 92-100.
6. J. Holtz, '*The Representation of AC Machine Dynamics by Complex Signal Flow Graphs'*, IEEE Transactions on Industrial Electronics, Vol. 42, No. 3, 1995, pp. 263-271

EE6325D LINEAR AND DIGITAL ELECTRONICS

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course outcomes:

CO1: Demonstrate the operation of BJT and CMOS operational amplifiers with special emphasis on non-ideal effects like offsets, finite impedance levels, finite gain bandwidth product, slew rate, PSRR etc.

CO2: Design various linear applications of opamps, various filters, sinusoidal oscillators etc., to carry out projects in Power Electronics.

CO3: Analyse and Design various nonlinear applications of opamps and comparators such as regenerative comparators, waveform generators, precision rectifiers, log-antilog amps etc.

Module 1: **(14 Hours)**

BJT and MOSFET Differential amplifiers and their analysis, Offset behaviour, Current sources for biasing inside a BJT/MOS IC –Properties of ideal Opamps, Internal description of a BJT Opamp, slew rate, internal description of a two stage MOS Opamp, Internal description of a Folded Cascode MOS Opamp, Dominant pole compensation –internal and external compensation.
The IOA model of an Opamp, principle of virtual short, Offset model for an Opamp, analysis and design of standard linear applications of Opamps Reference diodes and voltage references, linear voltage regulators Sinusoidal oscillators using Opamps

Active filtering – Butterworth low pass filter functions - low pass filter specifications - Order and cut off frequency of Butterworth function from low pass specifications –Sallen and Key second order LP section - gain adjustment in Butterworth LP filters –Butterworth high pass filters –

Second order wide band and narrow band band pass filters - multiple feedback single OPAMP LPF, HPF and BPF State variable active filter, Universal active filter.

Module 2: **(9 Hours)**

Regenerative Comparators, Comparator ICs , Square-Triangle – ramp generation, sine wave shaping, Function generator ICs , VCO Circuits, VFCs and FVCs and applications, Mono stable and Astable using Opamps, PLL and applications.
Precision rectification, Log and Anti-log amplifiers, IC multipliers, Trans conductance multiplier/divider, Time division multipliers
Analog switches - sample and hold amplifier –Data conversion fundamentals - D/A conversion – weighed resistor DAC - R/2R ladder DAC - current switching DAC - A/D conversion - quantiser characteristics -single slope and dual slope ADCs - successive approximation ADC - simultaneous ADC

Module 3: **(9 Hours)**

Basic digital circuits: Review of number systems and Boolean algebra - Simplification of functions using Karnaugh map - Boolean function implementation. . Examples of useful digital circuits:
Arithmetic Circuits, Comparators and parity generators, multiplexers and de multiplexers, decoders and encoders.
Combinational logic design: Combinational circuit design using Multiplexer, ROM, PAL, PLA.
Introduction to Sequential circuits: Latches and flip-flops (RS, JK, D, T and Master Slave) - Design of aclocked flip-flop – Flip-flop conversion - Practical clocking aspects concerning flip-flops.

Module 4: **(7 Hours)**
Design and analysis of sequential circuits: General model of sequential networks - State diagrams – Analysis and design of Synchronous sequential Finite Sate Machine – State reduction – Minimization and design of the next state decoder.
Counters: Design of single mode counters and multimode counters – Ripple Counters – Ring Counters – Shift registers counter design.
Practical design aspects: Timing and triggering considerations in the design of synchronous circuits – Setup time - Hold time – Clock skew.
Asynchronous sequential logic: Analysis and Design – Race conditions and Cycles – Hazards in combinational circuits – Hazard free realization.

Text Books and References:

1. Sedra & Smith: '*Microelectronic Circuits'*, Oxford University Press, 2004
2. Millman J.: Microelectronics, McGraw Hill,1999
3. Anvekar D.K. & Sonde B.S: '*Electronic Data Converters'*, Tata McGraw Hill,1994
4. Gayakwad R.A: '*OPAMPS & Linear Integrated Circuits'*, Prentice Hall of India,2002
5. Clayton G.B: '*Operational Amplifiers',* ELBS,2002
6. Frederiksen T.M: '*Intuitive Operational Amplifiers'*, McGraw Hill,1988
7. Roth C.H., '*Fundamentals of Logic Design'*, Jaico Publishers. IV Ed, 2003
8. W. I. Fletcher, '*An Engineering Approach to Digital Design'*, Prentice-Hall, Inc., Englewood Cliffs, NJ,1980
9. Tocci, R. J. and Widner, N. S., '*Digital Systems - Principles and Applications'*, Prentice Hall, 7th Ed, 200

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 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*', 4th Edition, Pearson, 2007, ISBN: 9788131710005, 8131710009.
3. Hazarathaiah Malepati: '*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 ofIndia Pvt. 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

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. Jurij Silc, 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 PSoC Newnes* (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

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 forms,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, 1984

EE6103D MEASUREMENTS AND INSTRUMENTATION

Pre-requisites: Nill

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.

EE6105D DIGITAL CONTROL: THEORY AND DESIGN

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Develop mathematical models of Digital Control Systems
CO2: Design and analyse digital control systems using classical techniques
CO3: Design and analyse SISO and MIMO digital control systems in the state space domain
CO4: Apply various techniques for the stability analysis of nonlinear digital control systems

Module 1: Introduction to digital control (9 hours)

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: Design of sampled data control systems (10 hours)

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

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: Nonlinear Digital control systems (11 hours)

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-tim.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

EE6102D OPTIMAL AND ROBUST CONTROL

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Apply the various concepts in the mathematical area of 'calculus of variation' for solving optimal control problems.

CO2: Develop methods of problem formulation pertaining to optimal control and design of optimal controllers

CO3: Analyse robustness of systems and develop skills useful in controlling systems when accurate mathematical models are unavailable

CO4: Design and synthesis robust controllers for practical systems

Module 1: (10 hours)

Calculus of variations: Examples of variational problems, Basic calculus of variations problem, Weak and strong extrema, Variable end point problems, Hamiltonian formalism and mechanics: Hamilton's canonical equations.

From Calculus of variations to Optimal control :Necessary conditions for strong extrema, Calculus of variations versus optimal control, optimal control problem formulation and assumptions, Variational approach to the fixed time, free end point problem.

The Pontryagin's Minimum principle: Statement of Minimum principle for basic fixed endpoint and variable end point control problems, Proof of the minimum principle, Properties of the Hamiltonian, Time optimal control problems. Minimum energy problems.

Module 2: (10 hours)

Linear Quadratic Regulator: Finite horizon LQR problem-Candidate optimal feedback law, Ricatti differential equations (RDE), Global existence of solution for the RDE. Infinite horizon LQR problem-Existence and properties of the limit, solution, closed loop stability.LQR using output feedback: Output feedback LQR design equations, Closed loop stability, Solution of design equations .Numerical solution of Riccatti Equations-Linear Quadratic tracking control: Tracking a reference input with compensators of known structure, Tracking by regulator redesign, Command generator tracker, Explicit model following design. Linear Quadratic Guassian controller (LQG) and Kalman-Bucy Filter: LQG control equations, estimator in feedback loop, steady state filter gain, constraints and minimizing control, state estimation using Kalman-Bucy Filter, constraints and optimal control.

Module 3: (10 hours)

Robust Control - Control system representations, System stabilities, Co-prime factorization and stabilizing controllers, Signals and system norms, Modelling of uncertain systems - Unstructured Uncertainties-Additive, multiplicative and other forms. Parametric uncertainty, Interval Systems, Structured uncertainties, Linear fractional transformation Robust design specifications: Small gain theorem and robust stabilization, Performance considerations, Structured singular values. Design - Mixed sensitivity optimization, 2-Degree of freedom design, Sub-optimal solutions, H_2 /H_∞ Systems.

Module 4: (9 hours)

Loop-shaping design procedures: Robust stabilization against Normalized co-prime factor perturbation, Loop shaping design procedures, μ - Analysis and Synthesis - Consideration of robust performance, μ-synthesis: D – K iteration method, Schur Compliment & Linear Matrix Inequalities: Some standard LMI problems – eigen - value problems, generalized eigen - value problems; Algorithms to solve LMI problems – Ellipsoid algorithm, interior point methods.

References:

1. D. W.Gu, P. Hr.Petkov and M.M.Konstantinov, '*Robust Control esign with MATLAB*', Springer, 2005.
2. Alok Sinha, *'Linear Systems-Optimal and Robust Controls',* CRC Press, 2007.
3. S. Skogestad and Ian Postlethwaite, *'Multivariable feedback control'*, John Wiley & Sons, Ltd, 2005.
4. G.E. Dullerud, F. Paganini, *'A course in Robust control theory-A convex approach'*, Springer, 2000.
5. Kemin Zhou with J.C. Doyle and K. Glover, *'Robust and Optimal control,'* Prentice Hall, 1996.
6. Kemin Zhou, John Comstock Doyle, Keith Glover, *'Robust and optimal control,'* PrenticeHall,1996.
7. Kemin Zhou, John Comstock Doyle, *Essentials of robust control*, Prentice Hall, 1998.
8. Stephen Boyd, Laurent El Ghaoul, Eric Feron, '*Linear Matrix Inequalities in System and ControlTheory',* SIAM, 1994.

EE6104D ADVANCED INSTRUMENTATION

Pre-requisite: Nil

Total hours: 39

L	T	P	C
3	0	0	3

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: Generalized measuring system (9 hours)

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

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

Module 3: Time domain analysis (10 hours)

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: Signal Processing and Conditioning (10 hours)

Study and analysis of amplitude modulation of measurements and design consideration of suchamplitudes modulated measurement systems. Requirements on instrument transfer function toensure 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

EE6106D STOCHASTIC MODELLING AND IDENTIFICATION OF DYNAMICAL SYSTEMS

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: Random variables & Stochastic processes (9 hours)

Probability spaces, random variables and probability distributions, expectations, transforms and generating functions, convergence. Gaussian, Exponential, Poisson, Weibull, Cauchy, Laplace distributions, Time series models, AR, MA ARMA, ARMAX, Markov process. Non-parametric and parametric methods for modelling.Fuzzy and probability.

Module 2: Stochastic process and development of system models(10 hours)

Elements of the theory of stochastic processes, Gauss Markov sequence model, Gauss Markov Process model-Discrete and Continuous-time Markov Chains (MCs): Transition probability matrix, Chapman-Kolmogorov equations; n-step transition and limiting probabilities, ergodicity, stationarity, correlation-random walk Brownian motion: Wiener process as a limit of random walk, White noise- PRBS-optimal smoothing, filtering and prediction for continuous and discrete linear systems.

Module 3: Bayesian estimation and System identification (10 hours)

Maximum likelihood estimation, linear mean square estimation- Parameter estimation for Time series models, AR, MA ARMA, ARMAX-efficiency and bias of estimators- minimizing prediction errors-Instrumental variable method-consistency and identifiability-Recursive methods- Matrix inversion lemma-RLS Algorithm-Weighted RLS algorithm- -Modelling with orthogonal functions and transforms -feature extraction-introduction to big data analytics- system identification experiments- design of inputs for system identification-persistent excitation-open loop and closed loop system identification.

Module 4: System Identification &Kalman Filter (10 hours)

Wiener Filter- estimation problem-Wiener Hopf equation- realizability- stochastic state estimation problem-optimal filtering and prediction-derivation of Kalman filter-Extended Kalman Filter-Unscented Kalman Filter-Combined state and parameter estimation-System identification for control.

References:

1. Schoukens, Johan,RikPintelon,YvesRolain,*“Mastering System Identification in 100 Exercises”*, Wiley IEEE Press, 2012
2. LingfengWang,Kay Chen Tan, *“Modern Industrial Automation Software Design”* , Wiley IEEE Press, 2012
3. Ravindra V. Jategaonkar, *“Flight Vehicle System Identification: A Time-Domain Methodology”,* Second Edition, Aerospace Research Central, American Institute of Aeronautics & Astronautics, USA, 2015.
4. J S Meditch, *“Stochastic Optimal Linear Estimation and Control*”, McGraw Hill Book Company, 1969
5. Charles K Chui, Guanrong Chen, “*Kalman Filtering with Real time Applications*”, Springer, 2009.

EE6108D NONLINEAR SYSTEMS AND CONTROL

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Analyse nonlinear systems using classical techniques
CO2: Analyse stability of non linear systems using advanced techniques
CO3: Analyse nonlinear feedback systems using time and frequency domain techniques
CO4: Design controllers for nonlinear systems using advanced methods

Module 1: Introduction and classical techniques (10 hours)

Characteristics of nonlinear systems – examples of systems exhibiting nonlinear phenomena- second order nonlinear autonomous systems- vector field representation- classification of equilibrium points – qualitative behavior near equilibrium points- limit cycles – existence of periodic orbits- Poincare-Bendixon criterion-Poincare index of equilibrium points- stability of periodic solutions- analysis of systems with piecewise constant inputs using phase plane analysis-Jump response.

Module 2: Lyapunov Stabilty (10 hours)

Existence and uniqueness of solutions of nonlinear state equations- stability of nonlinear systems - Lyapunov stability - local linearization and stability in the small – Centre manifold theorem- Direct method of Lyapunov - generation of Lyapunov function for linear and nonlinear systems- Variable gradient method-La Salle's Invariance theorem – Input to state stability - L stability - L stability of state models-Small gain theorem- Passivity- Positive real transfer functions-L_2 and Lyapunov stability-Passivity theorems- Loop transformation.

Module 3: Time domain analysis of feedback systems and perturbation techniques (7 hours)

Absolute stability of feedback interconnections of a linear part and nonlinear part- Circle criterion- Popov criterion- Frequency theorem- Harmonic linearization- filter hypothesis- Describing function of standard nonlinearities- amplitude and frequency of limit cycle using SIDF.Pertubation techniques- Regular perturbation- Singular perturbation-Reduced model- boundary- layer model- Tikhonov's theorem- slow and fast manifolds.

Module 4: Nonlinear system design tools (12 hours)

Control problems- stabilization via linearization - integral control via linearization- Gain scheduling-Feedback linearization-stabilization and tracking via state feedback control. Sliding mode control-Regulation via integral control- Lyapunov redesign- stabilization and nonlinear damping-Backstepping-Passivity based control- High gain observers. Linear Quadratic Regulators/Linear Quadratic Guassian Regulators-Numerical Solution for Riccatti Equations.

References:

1. Hassan K Khalil, *'Nonlinear Systems'*, Prentice - Hall International (UK) 1996
2. Slotine& W.LI, *'Applied Nonlinear Control'*, Prentice Hall, EngelwoodNewJersey 1991
3. AIsidori, *'Nonlinear Control systems'* Springer verlag New york 1995
4. S. Wiggins, *'Introduction to Applied Nonlinear Dynamical Systems and chaos'*, Springer Verlag New York 1990
5. H. Nijmeijer& A.J. Van Der schaft, *'Nonlinear Dynamic control Systems'*, Springer Verlag Berlin 1990.

6. Arther E Gelb & Vender Velde, *'Multiple input Describing function and Nonlinear System Design'*, MC Graw Hill 1968
7. Z Vukic, L Kuljaca, *'Nonlinear Control Systems',* Marcel Dekker, Inc., Newyork.

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

EE6125D ADAPTIVE CONTROL THEORY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Integrate the concepts of norms and spaces to be applied in adaptive control theory
CO2: Apply identification techniques for design of adaptive controller
CO3: Explain direct and indirect adaptive control techniques
CO4: Describe advanced adaptive control methods along with case studies and computer simulations

Module 1 : Preliminaries (10 Hours)

Norms and Lp spaces-positive definite matrices-input –output stability-Lp stability-small gain theorem-Positive real functions and stability-Analysis of Dynamical Systems ,Analysis of Solutions to Differential Equations., Equilibria and Stability. Invariant Sets. Lyapunov Stability Theory and Performance Analysis.,Nonautonomous Systems., LaSalle Extensions, Barbalat Lemma. Basic approaches to adaptive control -Applications of adaptive control. Introduction to types of Adaptive Control-Model Reference-Variable Structure-Sliding Mode- Neuro-Fuzzy-Learning Control-Intelligent Control using schematic diagrams and literature survey.

Module 2: Identification (10 hours)

Identification problem- Identification of linear time-invariant systems.Adaptive observers.Sufficient richness condition for parameter convergence. Equation error and output error methodsGradient *and* least-squaresalgorithms: Linear error equation. Gradient and normalized gradient algorithms. Least-squares algorithms (batch, recursive, recursive with forgetting factor). Convergence properties.Identification for Control.
Frequency-domain analysis and averaging approximations: Averaging of signals. Averaging theory for one-time scale and two-time scale systems.Applications to adaptive systems.

Module 3: Model Reference Adaptive Control (10 hours)

Indirect adaptive control: Pole placement adaptive control. Model reference adaptive control.Predictive control.Singularity regions and methods to avoid them.
Direct adaptive control: Filtered linear error equation. Gradient and pseudo-gradient algorithms.Strictly positive real transfer functions and Kalman-Yacubovitch-Popov lemma.Lyapunov redesign.Passivity theory. Direct model reference adaptive control. One case study of MRAC and computer based design.

Module 4: Methods in Adaptive Control (9 hours)

Adaptive Backstepping.,Adaptive Output Feedback Control, Adaptive NeuroControl., Examples of Adaptive Control.One case study and computer simulation.

References:

1. K.J. Astrom and B. Wittenmark, '*Adaptive Control',* Addison-Wesley, 2nd edition, 1995.
2. P.A. Ioannou& J. Sun, '*Robust Adaptive Control'*, Prentice Hall, Upper Saddle River, NJ, 1996..
3. I.D. Landau, R. Lozano, and M. M'Saad, '*Adaptive Control'*, Springer Verlag, London, 1998.
4. K.S. Narendra and A.M. Annaswamy, '*Stable Adaptive Systems'*, Prentice-Hall, 1989.
5. S. Sastry and M. Bodson*, 'Adaptive Control: Stability, Convergence, and Robustness'*, Prentice-Hall, 1989.

EE6126D ADVANCED TOPICS IN CONTROL SYSTEMS

Pre-requisite: Nil

Total hours: **39**

L	T	P	C
3	0	0	3

Course Outcomes

CO1: Apply the concepts of fuzzy and neuro-fuzzy systems in various control engineering problems
CO2: Explain the characteristics of MIMO systems and design MIMO controllers
CO3: Integrate the knowledge of chaotic systems in control and physiological systems
CO4: Design and analyse variable structure systems

Module 1: Neuro-Fuzzy Modelling and Control of Systems (10 hours)

Fuzzy Models- Mamdani and Takagi Sugeno Models- Construction of fuzzy models . Neural networks . Adaptive networks .supervised learning . Adaptive neuro-fuzzy inference systems- ANFIS architecture- ANFIS as a universal approximator - Simulation examples.

Module 2: Linear Multi-Input-Multi-Output Control Systems (10 hours)

Representations of MIMO systems- Equivalent transformations- Canonical forms- Solution of state equations- System response - Controllability and pole allocation- Observability and state estimator- System characterization by transfer matrix- Noninteractive and model matching control design.

Module 3: Chaos, fractals, applications and Aerospace Guidance Systems (10 hours)

Non linearsystems .chaos .fractals .dimensions .attractors .Lorenz attractor . Mandelbrot set, bifurcations,synthesis of some chaotic systems using neural net work. some control applications. fractals and chaos in medicine and physiology .
Introduction .trajectory aspects . inertial and optical sensors . inertial guidance for cruise vehicles, guidance and control of rocket vehicles . guidance and control of mobile-launched ballistic missiles.

Module 4: Variable Structure Systems (9 hours)

Introduction . Variable Structure Systems (VSS) . VSS for fast response . VSS for stability . VSS with sliding mode . Sliding mode motion . Existence Condition - Second order control problem . Sliding mode motion on switching line . Sliding mode motion on switching surface . Design of stable switching surface . Invariance Conditions in VSS . Variable structure model following control (VSMFC)

References

1. Robert Babuska :*'Fuzzy Modelling and Control'* - . International Series in Intelligent Technologies, Kluwer Academic Publications . 1998
2. Jang J SR ,Sun C T, Mizutani E : *'Neuro-fuzzy and Soft Computing . MATLAB curriculum Series*', Prentice Hall International, 1997
3. Apte Y.S., *'Linear Multivariable Control Theory*', Tata McGraw Hill Publishing Co. Ltd., 1994.
4. Chen C.T., '*Linear System Theory and Design*', Holt Reinhart and Winston Inc., 1984
5. Wolovich W.A., *'Linear Multivariable Systems*', Springer- Verlag , New york- Heidelberg- Berlin, 1974.
6. Thomas Kailath, *'Linear Systems*', Prentice Hall Inc., Englewood Cliffs, N.J. , 1980
7. Leondis C T .*'guidance and Control of Aerospace Vehicles*' . McGraw Hill Book Company Inc New York 1963
8. U. Itkis .*'Control Systems of variable structure*', New York, Wiley, 1976
9. A.S.I. Zinober (Edited by) – *'Deterministic Control of Uncertain Systems*', British Library Cataloguing in Publication Data, Peter Peregrinus Ltd. 1990
10. B. Drazenovic .*'The invariance conditions in variable structure systems*', Automatica, Vol. 5, pp 287-295, 1969.

11. K.K.D. Young .'*Design of Variable Structure Model Following Control Systems*', IEEE Transactions on Automatic Control, Vol. 23, pp-1079-1085 – 1978
12. A.S.I. Zinobar, O.M.E. El-Ghezawi and S.A.Billings – '*Multivariable variable structure adaptive model following control systems*' . Proc. IEE., Vol. 129., Pt. D., No.1, pp-6-12, 1982

EE6127D OPTIMAL ESTIMATION AND FILTERING

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: **39**

Course Outcomes

CO1: Integrate the concepts of random variables and processes for optimal estimation and filtering
CO2: Design linear optimal filters and predictors
CO3: Design smoothers and develop implementation algorithms
CO4: Design nonlinear filters by incorporating practical aspects

Module 1: Random Process and Stochastic Systems (10 hours)

Probability and random variables – statistical properties of random variables and random processes – linear random process models – shaping filters and state augmentation – mean and covariance propagation – relationship with model parameters – orthogonality principle

Module 2: Linear Optimal Filters and Predictors (10 hours)

Kalman filter – KalmanBucy Filter – Optimal linear predictors – Correlated noise sources – relation between KalmanBucy and winer filters- Quadratic loss function – Matrix Riccati differential equation and in discrete time – model equations for transformed variables – Application of Kalman filters

Module 3: Optimal Smoothers & Implementation Methods (10 hours)

Fixed Interval, fixed lag and fixed point smoothers – algorithms . Computer round off –effect of round off errors on Kalman filters- factorization methods for square root filtering – square root UD filters – other implementation methods

Module 4: Nonlinear Filtering & Practical Considerations (9 hours)

Quasi-linear filtering —extended Kalman filers – iterated EKF - sampling methods for nonlinear filtering- Detecting and correcting anomalies – bad data and missing data – stability of Kalman filters – Suboptimal- and reduced order filters – Memory throughput. Word length considerations - computational efforts – reduction – Error budgets and sensitivity analysis – optimizing measurement selection policies

References

1. Mohinder S Grewal and angus P Andrews, *'Kalman Filtering Theory and Practice Using MATLAB ',* John Wiley and Sons , 2008
2. B D O Anderson, John B Moore , *'Optimal Filtering'* , Prentice Hall Inc. 1979
3. Meditch J S, *'Stochastic Optimal Estimation and Control*', 1982

EE6128D VARIABLE STRUCTURE CONTROL SYSTEMS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: **39**

Course Outcomes

CO1: Design stable systems from unstable structures and simulate using MATLAB
CO2: Design sliding mode controllers and simulate using MATLB
CO3: Design stable switching surfaces for higher order systems and devise chattering reduction techniques.
CO4: Design variable structure model following control systems

Module 1: (10 hours)

Variable Structure Systems(VSS)-Introduction- Synthesis of stable systems from unstable structures- VSS for improving speed of response,-VSS for stability- simulation using MATLAB®-Simulation using SIMULINK®.

Module 2: (10 hours)

Variable structure systems with sliding mode- sliding mode motion- existence condition- equivalent control for sliding mode motion- sliding mode motion on switching line- Invariance conditions- Design of sliding mode controllers using feedback linearisation for non-linear systems- simulation of sliding mode controller using Matlab and simulink.

Module 3: (10 hours)

Sliding mode motion on switching surface- design of stable switching surfaces- design of sliding mode controller for higher order systems- Sliding mode controller design for a robotic manipulator- Chattering- Chattering reduction techniques.

Module 4: (9 hours)

Variable Structure Model Following Control (VSMFC) Systems- Conditions for perfect model following- sliding mode equivalent control- Sliding mode discontinuous control- Design of VSMFC for second order system- Design of VSMFC for higher order systems- Simulation using MATLAB and SIMULINK.

References:

1. U Itkis, *'Control Systems of Variable Structure*, New York,Wiley, 1976.
2. A S I Zinober, *'Deterministic Control of Uncertain Systems.*', British Library, 1990
3. B. Drazenovic, *'The invariance conditions in variable structure systems,'* Automatica., Vol. 5, pp 287 . 295, 1969.
4. K.K.D.Young, *'Design of Variable Structure Model Following Control Systems*'., IEEE Transactions on Automatic Control, Vol. 23, pp 1079-1085, 1978.
5. A.S.I. Zinobar, O.M.E. El-Ghezawi and S.A. Billings,*'Multivariable variable structure adaptive model following control system',*. Proc. IEE., Vol. 129, Pt.D., No.1, pp 6-12, 1982.
6. J.J. Slotine and S.S. Sastry, *'Tracking control of non-linear systems using sliding surfaces, with application to robot manipulators*'. International Journal of Control, 1983, Vol. 38, No.2, pp 465-492.
7. Vadim I. Utkin, *'Variable Structure Systems with Sliding Modes*'. IEEE Transactions on Automatic Control, April 1977, pp 212-222.

EE6130D QUANTITATIVE FEEDBACK THEORY

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the basics of QFT
CO2: Design QFT controller for SISO and MISO LTIV systems
CO3: Design QFT controller for MIMO LTIV systems
CO4: Apply discrete quantitative technique for MISO Systems

Module 1: Introduction to QFT (7 Hours)

Review of conventional control theory and introductory S-S theory- Need for QFT- QFT design objective- QFT basics- QFT design- Benefits of QFT- QFT applications

Module 2: QFT design for SISO and MISO LTIV systems (12 hours)

Basics of SISO feedback controlled systems- Basic frequency domain characteristics- closed loop specifications- Performance limitations of NMP or unstable systems- Loop shaping- Synthesis of LTI controllers for MISO LTI Plants- one DoF system-Two DoF system

Module 3: QFT design for MIMO LTIV systems (10 hours)

Specifications of desired closed loop performance measures- Representation of MIMO plants as SISO and MISO plants- One degree of freedom feedback system- Two DOF feedback system- Minimum phase diagonal elements- formulation using LFT notation- Sensitivity reduction and trade off non-minimum phase feedback systems.

Module 4: Discrete quantitative feedback technique (10 hours)

Bilinear transformation- Discrete MISO module with plant uncertainty- QFT W domain digitization design- Basic design procedure for a MISO sample data control system- QFT technique pseudo continuous time system- Digital controller implementation

References:

1. C.H. Houpis, S.I. Raslussen,'*Quantitative Feedback Theory: Fundamentals and applications'*, Marcel Dekker, 1999.
2. O. Yanid*, 'Quantitative Feedback Design of Linear and Nonlinear Control Systems'*, Kluwer Academic, Boston, 1999
3. I.M. Horowitz,*'Quantitative Feedback Theory'*, Vol 1, Colorado Press, Boulder, Colorado , 1993
4. M. Gopal,*'Digital Control and State Variable Methods'*, Tata McGraw- Hill publishing company Ltd., 2nd Ed., 2003
5. K.Ogata, *'Discrete-time Control Systems'*, Pearson Education Ltd., Singapore, 2ndEdn. ,2002.

EE6132D NUMERICAL METHODS FOR CONTROL SYSTEM DESIGN

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain the advanced topics of matrices in linear algebra
CO2: Explain the numerical methods linear algebra for system analysis
CO3: Apply numerical methods for control system analysis
CO4: Choose suitable numerical methods for control system design
CO5: Develop simulations on computer for control system studies

Module 1: (10 Hours)

Review of Linear Algebra: Vector spaces, Orthogonality, Matrices, Vector and Matrix Norms, Kronecker Product. Moore Penrose Inverse, Matrix Inversion Lemma, Recursive Algorithm- Large scale Matrix computations-Rank-Condition Number-Singular Values, Similarity Transformations, rotations-Hermitian matrices, Toeplitz matrix, some selected software and computer based exercises.

Module 2: (10 Hours)

Numerical Linear Algebra: Floating point numbers and errors in computations, Conditioning, Efficiency, Stability, and Accuracy, LU Factorization, Numerical solution of the Linear system Ax = b, QR factorization, Orthogonal projections, Least Squares problem, Singular Value Decomposition, Canonical forms obtained via orthogonal transformations, Heissenberg reduction of a matrix, sparse matrices, computations with sparse matrices, error analysis in various cases

Module 3: (10 Hours)

Control Systems Analysis: Linear State-space models and solutions of the state equations-Continuous time systems, discrete time systems- frequency response calculations- Controllability, Observability, Numerical Methods for Controllability and Observability, Difficulties with Theoretical Criteria, Stability, Inertia, and Robust Stability, Numerical solutions and conditioning of Lyapunov and Sylvester equations.

Module 4: (9 Hours)

Control Systems Design: Feedback stabilization, Eigenvalue assignment, Optimal Control, Quadratic optimization problems, Algebraic Riccati equations, Numerical Methods for State Feedback Stabilization, Eigenvalue Assignment (Pole-Placement) in both SISO and MIMO systems, Optimal Control via Riccati Equation- numerical solutions, H-infinity Control algorithms, Observer designs, State estimation and Kalman filter algorithms for discrete time state and parameter estimation problems. Computer based simulation of selected control systems.

References:

1. G. Strang, "*Introduction to Linear Algebra*", (5th Ed), SIAM, USA, 2016
2. B.N. Datta, "*Numerical Methods for Linear Control Systems*", Elsevier Academic Press, 2005.
3. G.H. Golub & C.F. Van Loan, "*Matrix Computations*", (4th Ed), John Hopkins University Press, 2012
4. J .H. Wilkinson, "*The Eigenvalue Problem*", Oxford University Press, 1992.
5. G Meurant, "*Computer Solution of Large Linear Systems*", Elsevier, North Holland, 2005
6. John Dorsey, "*Continuous and Discrete Control Systems*", McGrawHill, 2002
7. Mariano Martin Martin, *"Introduction to Software for Chemical Engineers*", CRC Press, 2015
8. Warren F Phillips, "*Mechanics of Flight*"(2nd Ed) John Wiley & Sons, 2010

EE6134D NETWORKED CONTROL AND MULTIAGENT SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Integrate the basic concepts to formulate networked control problems
CO2: Describe various decentralized control strategies for networked control systems
CO3: Develop various control strategies for multi-agent robotics
CO4: Develop models and strategies for mobile sensor and communication networks

Module 1: Basic concepts in networked control (8 Hours)

Review of Graph Theory-Connected Graph-Incidence Matrix-Tree-cutset-loop/cycles-Minimum Spanning Tree-Network Models -graphs, random graphs, random geometric graphs, state-dependent graphs-Networked control systems-Proximity graphs - Algebraic and spectral graph theory - Connectivity: Cheeger's inequality -switching networks- From biological swarms to graph-based models-Rendezvous: A canonical problem

Module 2: Decentralized Control (10 hours)

The agreement protocol: static case- Reaching decentralized agreements- Consensus equation: Static case- Leader networks and distributed estimation- Discrete time consensus.
The agreement protocol: dynamic case: Switched networks- Lyapunov-based stability- Consensus equation: Dynamic case-Biological models: Flocking and swarming- Alignment and Kuramoto's coupled oscillators.
Distributed estimation -Computational, communications, and controls resources in networked control systems-Distributed control- Convex Optimization -Optimization-based control design.

Module 3: Multi Agent Robotics (11 hours)

Formations - Graph rigidity -Persistence -Formation control, sensor and actuation models-distance based formations, rigidity, position based formations, formation infeasibility -Consensus problem- static, dynamic, distributed estimation, leader-follower architectures for consensus-Reaching decentralized agreements through cooperative control- leader-follower networks-Network controllability- Network feedback- Averaging Systems-Positive Systems- nonholonomic, double integrator, rigid body dynamics-Collision avoidance: potential fields, navigation functions. Introduction to artificial intelligence & deep learning for multi-agent robotics.

Module 4: Mobile sensor and communication networks (10 hours)

Sensor networks: Coverage control- Coverage and detection problems-Gabriel and Voronoi graphs-voronoi-based cooperation strategies-Random graphs - LANdroids: Communication networks - Communication models- mobile communications networks- connectivity, connectivity maintainance, sampling, delays, packet losses, quantization, security -Swarming-sensor networks: sensing constraints, aggregation, dispersion, coverage control, deployment, flocking. Internet of things(IOT)

References:

1. Mehran Mesbahi and Magnus Egerstedt, '*Graph Theoretic Methods in Multiagent Networks*,' Princeton University Press, 2010.
2. F. Bullo, J. Cortes, and S. Martinez, '*Distributed Control of Robotic Networks'*, Princeton, 2009.
3. C. Godsil and G. Royle, '*Algebraic Graph Theory'*, Springer, 2001.
4. P. J. Antsaklis and P. Tabuada,, '*Networked Embedded Sensing and Control',* Springer 2006.

5. C. Godsil and G. Royle, *'Algebraic Graph Theory'*, Springer, 2001.
6. M. Mesbahi and M. Egerstedt,*'Graph Theoretic Methods in Multi-Agent Networks'*, Princeton University Press, 2010.
7. Wei Ren, Randal W. Beard, *'Distributed Consensus in Multi-vehicle Cooperative Control'*, Communications and Control Engineering Series, Springer-Verlag, London, 2008

EE6135D FLEXIBLE STRUCTURES

Pre-requisite:Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Develop basic mathematical models for flexible structures
CO2: Integrate different finite element methods for the modelling of flexible structures
CO3: Design of various controllers for flexible structures
CO4: Simulate the control strategies in various applications of flexible structures.

Module 1: Introduction to flexible structures (7 Hours)

Flexible structures -The Finite Element Method – The element characteristic matrix – Element assembly and solution for unknowns – Summary of finite element history. Basic equations of elasticity – Strain-displacement relations – Theory of stress and deformation – Stress-strain-temperature relations.

Module 2: Modelling of flexible structures (13 hours)

Stationary Principles, Rayleigh-Ritz Method and Interpolation: - Principle of stationary potential energy – Problems having many d.o.f – Potential energy of an elastic body – The Rayleigh-Ritz method – Piecewise polynomial field – Finite element form of Rayleigh-Ritz method – Finite element formulations derived from a functional – Interpolation – Shape functions for C0 and C1 elements – Lagrangian and Hermitian interpolation functions for one dimensional elements – Lagrangian interpolation functions for two and three dimensional elements Introduction to Weighted Residual Method: -Some weighted residual methods – Galerkin finite element method – Integration by parts – Axially loaded bar – Beam – Plane elasticity

Module 3: Analysis and control of flexible structures (12 hours)

Model order reduction for control design**:** Time Domain- modal cost analysis and component cost analysis-balancing method of model reduction. Frequency domain - Routh approximation method-Hankel norm model reduction
Passive control and active control-Feedback and feed forward control-LQR control-decentralised/hierarchical control-model reference adaptive control- robust control theory.

Module 4: Simulation studies of flexible structures (7 hours)

Applications of flexible structures- Flexible structures in robotics- Flexible aerospace structures- Control of flexible links

References:

1. Cook, Robert D., '*Concepts and applications of finite element analysis*', John Wiley & Sons, 2007.
2. Desai, Chandrakant S. '*Elementary finite element method." Civil Engineering and Engineering Mechanics Series', Englewood Cliffs': Prentice-Hall, 1979*
3. Chandrupatla, Tirupathi R.. '*Introduction to finite elements in engineering'*. Vol. 2. Upper Saddle River, NJ: Prentice Hall, 2002.
4. Krishnamoorthy, C. S. '*Finite element analysis: theory and programming'*. Tata McGraw-Hill Education, 1995.
5. Zienkiewicz, Olgierd Cecil, . '*The finite element method*', Vol. 3. London: McGraw-hill, 1977.
6. Junkins, John L. *'Introduction to dynamics and control of flexible structures'.* , 1993.
7. Cavallo, Alberto, et al. *'Active control of flexible structures–From modelling to implementation'*, Springer, 2010.

EE6138D SELECTED TOPICS IN CONTROL

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Summarize and apply the concept of modeling and analysis of Fractional order systems.
CO2: Relate and design the Fractional order Controllers and identify its implementation issues.
CO3: Summarize and apply the concept of modeling and analysis of Time-Delay systems.
CO4: Relate and design the controller for time-delay systems.

Module 1: Fractional order Systems (10 Hours)

Need for Fractional Order, Fractional-order Operators: Definitions and Properties, Fractional-order Integrals, Fractional-order Derivatives, Fractional-order Differential Equations, Fractional-order Systems Models and Representations, Stability, Analysis of Time and Frequency Domain Responses, Bode's Ideal Loop Transfer Function.
State-space Representation and Analysis: Continuous-time LTI State-space Realizations, Solution of the State Equation of Continuous LTI Commensurate-order Systems-Inverse Laplace Transform, Jordan Matrix Decomposition and Cayley–Hamilton Methods, Stability Analysis. Controllability and Observability of Continuous LTI Commensurate-order Systems.

Module 2: Fractional order Controllers and Implementation (10 hours)

Need for Fractional-order Control, Concept of Integral and Derivative Action, Fractional-order PID Controller, F-MIGO: Fractional *M*s Constrained Integral Gain Optimization Method for Fractional-order Proportional Integral Controller Tuning for First-order Plus Delay Time Plants. Fractional-order PD Controller Design for a Class of Second-order Plants. Design Specifications and Tuning Problem of Fractional-order PID Controller. Tuning of Fractional-order Lead-lag Compensators. Robust Control Techniques- CRONE.
Continuous-time Implementations of Fractional-order Operators- Continued Fraction Approximations, Oustaloup Recursive Approximations Modified Oustaloup Filter, Discrete-time Implementation of Fractional-order Operators-FIR Filter Approximation, Discretization Using The Tustin Method with Prewarping

Module 3: Time-Delay Systems (10 hours)

Model with Time-Delay in engineering applications; system-theoretic preliminaries, Mathematical modelling of time-delay systems, frequency domain & modal analyses; state space and rational approximations, Stability analysis, stability notions; frequency sweeping; Lyapunov's method

Module 4: Controller for Time-Delay Systems (9 hours)

Stabilization methods- fixed-structure controllers; finite spectrum assignment; coprime factorization. Dead-time compensation –PID Control , Smith-Predictor Based Control and its modifications; implementation issues, Finite-spectrum Assignment, Handling uncertain delays-Lyapunov-based methods; unstructured uncertainty embedding, Optimal control and estimation-H2 optimizations

References:

1. Concepción A. Monje, YangQuan Chen, Blas M. Vinagre, DingyüXue and Vicente Feliu, "*Fractional-order Systems and Controls-Fundamentals and Applications*" , Springer-Verlag London Limited , 2010.
2. Sabatier**, J.,** Lanusse**, P.,** Melchior**, P.,** Oustaloup**,** A "*Fractional Order Differentiation and Robust Control Design-CRONE, H-infinity and Motion Control*", Springer, 2015
3. Emilia Fridman, "*Introduction to Time-Delay Systems: Analysis and Control*", Springer International Switzerland 2014.
4. J. E. Marshall, H. Gorecki, A. Korytowski, and K. Walton, *Time-Delay Systems: Stability and Performance Criteria with Applications* . London: Ellis Horwood, 1992.

5. K. Gu, V. L. Kharitonov, and J. Chen, "*Stability of Time-Delay Systems*", Boston: Birkhauser, 2003.
6. R. F. Curtain and H. Zwart, *"An Introduction to Infinite-Dimensional Linear Systems Theory*",. New York: Springer-Verlag, 1995.
7. Qing –ChnagZhong, *"Robust Control of Time-delay System*", Springer-Verlag London, 2006.

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 smart grid 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. Amirnaser Yezdani, 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.

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 equipments 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

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

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.

EE6402D PROCESS CONTROL AND AUTOMATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the process modelling, process dynamics and process instrumentation
CO2: Analyze various feedback and feed forward control strategies and design the control system based on frequency response analysis.
CO3: Demonstrate the process control of MIMO systems, control loop interactions, singular value analysis, decoupling control and real time optimization.
CO4: Describe advanced control strategies – Model predictive control, Adaptive control, Inferential Control and Batch process control.
CO5: Perform plant wide control design, instrumentation for process monitoring and statistical process Control.

Module 1: (9 hours)

Process Modeling- Introduction to Process control and process instrumentation-Hierarchies in process control systems-Theoretical models-Transfer function-State space models-Time series models-Development of empirical models from process data-chemical reactor modeling-. Analysis using softwares

Module 2: (10 hours)

Feedback & Feedforward Control- Feedback controllers-PID design, tuning, trouble shooting-Cascade control- Selective control loops-Ratio control-Control system design based on Frequency response Analysis-Direct digital design-Feedforward and ratio control-State feedback control- LQR problem- Pole placement -Simulation using softwares-Control system instrumentation-Control valves- Codes and standards- Preparation of P& I Diagrams.

Module 3: (10 hours)

Advanced process control-Multi-loop and multivariable control-Process Interactions-Singular value analysis-tuning of multi loop PID control systems-decoupling control-strategies for reducing control loop interactions-Real-time optimization-Simulation using softwares

Module 4: (10 hours)

Model predictive control-Batch Process control-Plant-wide control & monitoring- Plant wide control design-Instrumentation for process monitoring-Statistical process control-Introduction to Fuzzy Logic in Process Control-Introduction to OPC-Introduction to environmental issues and sustainable development relating to process industries. Comparison of performance different types of control with examples on softwares

References:

1. Seborg, D.E., T.F. Edgar, and D.A. Mellichamp, '*Process Dynamics and Control'*, John Wiley , 2004
2. Johnson D Curtis, '*Instrumentation Technology'*, 7th Edition, Prentice Hall India, 2002.
3. Bob Connel, *Process Instrumentation Applications Manual*, McGrawHill, 1996.
4. Edgar, T.F. & D.M. Himmelblau, '*Optimization of Chemical Processes'*, McGrawHill Book Co, 1988.
5. Macari Emir Joe and Michael F Saunders, '*Environmental Quality Innovative Technologies and Sustainable Development'*, American Society of Civil Engineers, 1997.
6. Nisenfeld,A.E ,(Ed), '*Batch Control: practical guides for measurement and control*, Instrument Society of America, 1996.
7. Sherman, R.E. (Ed), '*Analytical instrumentation'*, Instrument Society of America, 1996.

8. Shinskey, F.G., *Process Conrol Systems: Applications, Design andTuning* ,3rd Edition, McGrawHill Book Co, 1988.
9. B. Wayne Bequette, '*Process control: modeling, design, and simulation'*, Prentice Hall PTR, 2003
10. K. Krishnaswamy, '*Process Control'*, New Age International, 2007

EE6403D COMPUTER CONTROLLED SYSTEMS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: Identify the scientific and mathematical principles and methodologies relevant to computer control of systems.
CO2: Describe the fundamentals of PLC and its architecture.
CO3: Explain the PLC programming fundamentals, process logic and human machine interface.
CO4: Describe DCS architecture and configuration.
CO5:Analyze in detail the case studies of PLC, SCADA and DCS.
CO6: Perform inter task communication, synchronization and real time memory management.

Module 1: Multivariable Control (11 hours)

Multivariable control- Basic expressions for MIMO systems- Singular values- Stability norms- Calculation of system norms- Robustness- Robust stability- H2 / H∞ Theory- Solution for design using H2 / H∞ - Case studies. Interaction and decoupling- Relative gain analysis- Effects of interaction- Response to disturbances- Decoupling- Introduction to batch process control.

Module 2: Programmable Logic Controllers (9 hours)

Programmable logic controllers- Organisation- Hardware details- I/O- Power supply- CPU- Standards- Programming aspects- Ladder programming- Sequential function charts- Man- machine interface- Detailed study of one model- Case studies.

Module 3: Large Scale Control System (11 hours)

SCADA: Introduction, SCADA Architecture, Different Communication Protocols, Common System Components, Supervision and Control, HMI, RTU and Supervisory Stations, Trends in SCADA, Security Issues

DCS: Introduction, DCS Architecture, Local Control (LCU) architecture, LCU languages, LCU - Process interfacing issues, communication facilities, configuration of DCS, displays, redundancy concept - case studies in DCS.

Module 4: Real Time Systems (8 hours)

Real time systems- Real time specifications and design techniques- Real time kernels- Inter task communication and synchronization- Real time memory management- Supervisory control- direct digital control- Distributed control- PC based automation.

References:

1. Shinskey F.G., '*Process control systems: application, Design and Tuning'*, McGraw Hill International Edition ,Singapore,1988.
2. Be.langer P.R., 'Control *Engineering: A Modern Approach'*, Saunders College Publishing , USA, 1995.
3. Dorf, R.C. and Bishop R. T , '*Modern Control Systems'* , Addison Wesley Longman Inc., 1999
4. Laplante P.A.,'*Real Time Systems: An Engineers Handbook'*, Prentice Hall of India Pvt. Ltd., New Delhi, 2002.
5. Constantin H. Houpis and Gary B. Lamont, '*Digital Control systems'*, McGraw Hill Book Company, Singapore, 1985.
6. Stuart A. Boyer: 'SCADA-*Supervisory Control and Data Acquisition'*, Instrument Society of America Publications, USA, 1999

7. Gordon Clarke, Deon Reynders, '*Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems*', Newnes Publications, Oxford, UK,2004
8. Efim Rosenwasser, Bernhard P. Lampe, '*Multivariable computer-controlled systems: a transfer function approach'*, Springer, 2006

EE6404D INDUSTRIAL INSTRUMENTATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the industrial measurement system and different elements involved in it.
CO2: Describe the various sensors and transducers used for different industrial variables like torque, pressure, etc.
CO3: Explain signal conditional circuits like amplifiers, filters, ADC, etc. for working industrial measurement systems.
CO4: Analyze the static and response characteristics of first order and higher order system.

Module 1: (11 hours)

Industrial measurement systems – different types of industrial variables and measurement systems elements – sensors and transducers for different industrial variables like pressure, torque, speed, temperature etc– sensor principles – examples of sensors – sensor scaling – Industrial signal conditioning systems- Amplifiers – Filters – A/D converters for industrial measurements systems –review of general Industrial instruments.

Module 2: (8 hours)

Calibration and response of industrial instrumentation - standard testing methods and procedures – Generalized performance characteristics – static response characterization – dynamic response characterization - zero order system dynamic response characterizations – first order system dynamic response second order system dynamic response – higher order systems - Response to different forcing functions such as step, sinusoidal etc. to zero, first, second third and higher orders of systems.

Module 3: (11 hours)

Regulators and power supplies for industrial instrumentation – linear series voltage regulators – linear shunt voltage regulators – integrated circuit voltage regulators – fixed positive and negative voltage regulators – adjustable positive and negative linear voltage regulators – application of linear IC voltage regulators - switching regulators –single ended isolated forward regulators- half and full bridge rectifiers. pH and conductivity sensors. Piezo-electric and ultrasonic sensors and its application in process and biomedical instrumentation. Measurement of viscosity, humidity and thermal conductivity

Module 4: (9 hours)

Servo drives – servo drive performance criteria – servomotors shaft sensors and coupling – sensors for servo drives – servo control loop design issues- stepper motor drives types and characteristics – hybrid stepper motor – permanent magnet stepper motor – hybrid and permanent magnet motors – single and multi step responses.

References:

1. Ernest O. Doebelin, '*Measurement systems applications and design*', McGraw – Hill International Editions, McGraw- Hill Publishing Company, 1990
2. Patric F. Dunn University of Notre Dame, '*Measurement and Data Analysis for engineering and science*', Mc Graw Hill Higher education, 1995
3. Randy Frank, '*Understanding Smart Sensors*', Artec House Boston. London, 2000
4. Muhamad H Rashid, '*Power electronics handbook*', ACADEMIC PRESS, 2007
5. K Krishnaswamy, '*Industrial Instrumentation*', New Age International Publishers, New Delhi, 2003
6. Gregory K. McMillan, Douglas M. Considine, '*Process/Industrial Instruments and Controls Handbook*',5th Edition, Mc Graw Hill 1999

7. Steve Mackay, Edwin Wright, John Park, ‘*Practical Data Communications for Instrumentation and Control’*, Newness Publications, UK, 2003
8. John O Moody, Paros J Antsaklis, ‘*Supervisory Control of discrete event systems using petrinets’*, PHI, 2002
9. James L Peterson, ‘*Petrinet theory and modeling of system’*, 1981

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

Total hours: 39

L	T	P	C
3	0	0	3

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.

EE6424D ROBOTIC SYSTEMS AND APPLICATIONS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: Apply the mathematics of spatial descriptions and transformations
CO2: Explain the robot system components that combine embedded hardware, software and mechanical systems.
CO3: Describe manipulator kinematics and mechanics of robotic motion.
CO4: Explain the manipulator dynamics, transformation of acceleration, and robot controller architecture
CO5: Apply artificial intelligence techniques in robotics
CO6: Explain various robotics applications and their associated components and control systems.

Module 1: (8 hours)

Mathematics of Spatial Descriptions and Transformations-Robot definition. Robot classification. Robotic system components- Notations- Position definitions- Coordinate frames - Different orientation descriptions - Free vectors- Translations, rotations and relative motion - Homogeneous transformations.

Module 2: (10 hours)

Manipulator Kinematics and Mechanics of Robot Motion-Link coordinate frames- Denavit-Hartenberg convention - Joint and end-effector Cartesian space-Forward kinematics transformations of position-Inverse kinematics of position-Translational and rotational velocities -Velocity Transformations- Manipulator Jacobian -Forward and inverse kinematics of velocity-Singularities of robot motion-Static Forces-Transformations of velocities and static forces -Joint and End Effector force/torque transformations-Derivation for two link planar robot arm as example.

Module 3: (12 hours)

Manipulator Dynamics- Transformations of acceleration- Trajectory Planning- Control-Lagrangian formulation- Model properties - Newton-Euler equations of motion- Derivation for two link planar robot arm as example- Joint space-based motion planning - Cartesian space-based path planning-Independent joint control- Feed-forward control-Inverse dynamics control-Robot controller architectures. Implementation problems.

Module 4: (9 hours)

Robot Sensing and Vision Systems- Sensors-Force and torque sensors-low level vision-high level vision-Robot Programming languages-Introduction to Intelligent Robots-Robots in manufacturing automation.

References:

1. Fu, K.S., R.C. Gonzalez, C.S.G. Lee, '*Robotics: Control, Sensing, Vision & Intelligence*', McGrawHill, 1987.
2. Craig, John J., '*Introduction to Robotics: Mechanics & Control*', 2nd Edition, Pearson Education, 1989.
3. Gray J.O., D.G. Caldwell(Ed), '*Advanced Robotics & Intelligent machines*', The Institution of Electrical Engineers, UK, 1996.
4. Groover, Mikell P, '*Automation, Production Systems & Computer Integrated manufacturing*', Prentice hall India, 1996.
5. Groover Mikell P., M. Weiss, R.N. Nagel, N.G. Odrey, '*Industrial Robotics*', McGrawHill, 1986.
6. Janakiraman, P.A., '*Robotics & Image Processing*', Tata McGrawHill, 1995.

7. Sciavicco, L., B. Siciliano, '*Modelling & Control of Robot Manipulators*', 2nd Edition, Springer Verlag, 2000.
8. Robin R. Murphy, '*An introduction to AI Robotics*', MIT Press, 2008
9. Oliver Brock, Jeff Trinkle and Fabio Ramos, '*Robotics-Science and Systems*', Vol. IV, MIT Press 2009

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.

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 & 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*, MIT press, 2009..

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

EE6521D 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 o 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 of HVDC systems for digital dynamic simulation – Dynamic interaction between DC and AC systems. Power flow analysis of AC-DC systems. Transient stability analysis.

References

1. Kimabrk E.W., HVDC Transmission, 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.

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.