CURRICULUM AND SYLLABUS OF

M.TECH. DEGREE PROGRAMME IN

POWER ELECTRONICS

DEPARTMENT OF ELECTRICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

CALICUT

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.

Department of Electrical Engineering

The Program Educational Objectives (PEOs) of M.Tech. in Power Electronics

Sl. No.	Program Educational Objectives
PEO 1	To equip the engineering graduates with adequate knowledge and skills in the areas of Power Electronics so as to excel in advanced level jobs in modern industry and/ or teaching and/or higher education and/or research.
PEO 2	To transform engineering graduates to expert engineers so that they could comprehend, analyse, design and create novel products and solutions to problems in the areas 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

Department of Electrical Engineering

The Program Outcomes (POs) of M.Tech. in Power Electronics

At the end of the Program the students will be able to:

Sl. No.	Program Outcome	Graduate Attribute
PO 1	Achieve the ability to analyse and model the problems in the field of power electronics and solve such problems using the classy knowledge in the advanced and latest topics in power electronics.	Scholarship of Knowledge
PO 2	Acquire necessary skills to critically model, analyse and solve all the engineering problems in the field of power electronics.	Critical Thinking
PO 3	Could analyse all the engineering problems in the area of power electronics through mathematical modeling as well as other possible methods so that a realistic, optimal, feasible and apposite engineering solution could be provided for them.	Problem Solving
PO 4	Acquiring the awareness regarding the most recent advancements as well as current topics of research in the field of power electronics, and critically analyse the problems of this field to provide preeminent engineering solutions for all such problems through methodical research.	Research Skill
PO 5	Acquire the essential skills to learn and exploit the modern tools and technologies for solving the real life problems in the field of power electronics.	Usage of modern technology
PO 6	Capability to work with a team of engineers/researchers to take up and solve new challenges of multidisciplinary nature in the field of power electronics.	Collaborative and Multidisciplinary work
PO 7	Ability to take up the research and development projects in the area of power electronics, which involves administrative and financial challenges including total project management and time-bound completion of them.	Project Management and Finance
PO 8	Acquire the enhanced communication skills of oral, writing as well as drawing natures, so that the ideas could be disseminated flawlessly and precisely.	Communication

PO 9	Develop the attitude to sustain the lifelong learning process by the way of participating in various professional activities and utilise the skills and knowledge so acquired to solve the problems in the field of power electronics.	Life-long Learning
PO 10	Best utilise the acquired knowledge to solve the real life problems associated with the common man of the society in the most ethical manner, so that the standard of life will be enhanced.	Ethical Practices and Social Responsibility
PO 11	Attain the ability to understand and learn the novel ideas through the self learning process and to utilise such knowledge in solving the problems in the area of power electronics.	Independent and Reflective Learning

Department of Electrical Engineering

Curriculum for M. Tech. in Power Electronics

Semester 1

Course Code	Course Title	L	T	P/S	C
MA6003	Mathematical Methods for Power Engineering	3	0	-	3
EE6301	Power Electronics Circuits	3	0	-	3
EE6303	Dynamics of Electrical Machines	3	0	-	3
	Elective -1	3	0	-	3
	Elective -2	3	0	-	3
	Elective -3	3	0	-	3
EE6391	Power Electronics Lab	-	-	3	2
Total		18	0	3	20

Semester 2

Course Code	Course Title	L	T	P/S	C
EE6302	Advanced Power Electronic Circuits	3	0	-	3
EE6304	Advanced Digital Signal Processing	3	0	-	3
EE6306	Power Electronic Drives	3	0	-	3
EE6308	FACTS and Custom Power	3	0	-	3
	Elective -1	3	0	-	3
	Elective -2	3	0	-	3
EE6392	Mini Project	-	-	3	1

EE6394	Seminar	-	-	3	1
Total		18	0	6	20

Semester 3

Course Code	Course Title	L	T	P/S	C
EE7391	Main Project -1	0	0	16	8
Total		0	0	16	8

Semester 4

Course Code	Course Title	L	T	P/S	C
EE7392	Main Project -2	0	0	24	12
Total		0	0	24	12

LIST OF ELECTIVES

Sl. No	Code	Title	Credits
1	EE6321	Power Semiconductor Devices and Modeling	3
2	EE6322	Static VAR Controllers and Harmonic Filtering	3
3	EE6323	Digital Simulation of Power Electronic Systems	3
4	EE6324	Advanced Control of PWM Inverter-fed Induction Motor Drives	3
5	EE6325	Switched Mode and Resonant Converters	3
6	EE6327	Linear and Digital Electronics	3
7	EE6102	Optimal and Adaptive Control	3
8	EE6121	Data Acquisition and Signal Conditioning	3
9	EE6122	Biomedical Instrumentation	3
10	EE6125	Digital Control Systems	3
11	EE6129	Artificial Neural Networks and Fuzzy Systems	3
12	EE6204	Digital Protection of Power systems	3
13	EE6222	Power Quality	3
14	EE6401	Energy Auditing & Management	3
15	EE6402	Process Control & Automation	3
16	EE6403	Computer Controlled Systems	3
17	EE6404	Industrial Load Modeling & Control	3
18	EE6406	Industrial Instrumentation	3
19	EE6421	Advanced Micro-Controller Based Systems	3
20	EE6422	Engineering Optimization	3
21	EE6424	Robotic Systems and Applications	3
22	EE6426	Distribution systems Management & Automation	3
23	EE6428	SCADA Systems & Applications	3

****Any other subject offered in the Institute with approval from the Programme Coordinator

BRIEF SYLLABUS

MA6003: Mathematical Methods for Power Engineering

REQUIRED COURSE

L	T	P	C
3	0	0	3

Pre-requisite: Nil

Total hours: 42 Hrs.

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

EE6301: Power Electronic Circuits

REQUIRED COURSE

L	T	P	C
3	0	0	3

Pre-requisite: Nil

Total hours: 42 Hrs.

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

EE6303: Dynamics of Electrical Machines

REQUIRED COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs.

Electro dynamical Equations and their Solution .Linearisation of the Dynamic Equations and Small SignalStability. The Primitive 4 Winding Commutaor Machine- The Commutator Primitive Machine The Complete Voltage Equation of Primitive 4 Winding CommutatorMachine . The Torque Equation . Analysis of Simple DC Machines using the Primitive Machine Equations. The Three Phase Induction Motor . Transformed Equations . Different Reference Frames for Induction Motor Analysis Transfer Function Formulation. The Three Phase Salient Pole Synchronous Machine . Parks Transformation-SteadyState Analysis . Large Signal Transient -Small Oscillation Equations in State Variable form .DynamicalAnalysis of Interconnected Machines . Large Signal Transient Analysis using Transformed Equations . TheDC Generator/DC Motor System . The Aslternator /Synchronous Motor System . The Ward-LeonardSystem

EE6302: Advanced Power Electronic Circuits

REQUIRED COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs.

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

EE6304: Advanced Digital Signal Processing

REQUIRED COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

Discrete time signals, systems and their representations - Discrete Fourier series- Discrete Fourier transform- Z- transform- Computation of DFT Digital filter design and realization structures Basic IIR and FIR filter realization structures- Signal flow graph representations Quantization process and errors- Coefficient quantisation effects in IIR and FIR filters- A/D conversion noise- Arithmetic round-off errors-

Dynamic range scaling- Overflow oscillations and zero input limit cycles in IIR filters Statistical signal processing Linear Signal Models -Power spectrum estimation- Spectral analysis of deterministic signals . Estimation of power spectrum of stationary random signals-Optimum linear filters-Optimum signal estimation-Mean square error estimation-Optimum FIR and IIR filters.fuzzy systems - hybrid systems.

EE6306: Power Electronic Drives

REQUIRED COURSE

Pre-requisite: Nil

Total hours: 42 Hrs

L	T	P	C
3	0	0	3

Introduction to Motor Drives - stability criteria D.C Motor Drives - System model motor rating - Chopper fed and 1-phase converter fed drives Induction Motor Drives - Speed control by varying stator frequency and voltage - Variable frequency PWM-VSI drives - Variable frequency square wave VSI drives – Variablefrequency CSI drives - Speed control by static slip power recovery. - Vector control of 3 phase squirrelcage motors - Synchronous Motor Drives - load commutated inverter drives. PMSM Drives, Switchedreluctance Drive.

EE6308: FACTS and Custom Power

REQUIRED COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

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

EE6321: Power Semiconductor Devices and Modeling

ELECTIVE COURSE

L	T	P	C
3	0	0	3

Pre-requisite: Nil

Total hours: 42 Hrs

Power Diodes, Thyristors, Triacs, Gate Turnoff Thyristor (GTO). V-I Characteristics . Turn on Process

Snubber Requirements and Snubber Design. Power BJTs . Basic Structure and I-V Characteristics FBSOAand RBSOA Curves. Switching Characteristics Snubber Requirements for BJTs and Snubber Design -Switching Aids.Power MOSFETs - Basic Structure . V-I Characteristics . Turn on Process . Turn onTransient Turn off Transient dv/dtlimitations . Gating Requirements . Gate Charge - Ratings of MOSFETs.
FBSOA and RBSOA Curves . -Snubber Requirements .Insulated Gate Bipolar Transistors (IGBTs) . BasicStructure and Operation .Latch up IGBT Switching Characteristics IGBT Turn on Transient . IGBT Turnoff Transient- Snubber Requirements and Snubber Design. New power semiconductor devices . Thermaldesign of power electronic equipment . Modelling of power semiconductors (principles) . Simulation tools.
Gating Requirements for Thyristor, Component Temperature Control and Heat Sinks . Modelling of powerdiode - Modelling of power MOSFET - Modelling of bipolar transistor - Modelling of IGBT

EE6322: Static Var Controllers & Harmonic Filtering

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

Fundamentals of Load Compensation , Power Qulity Issues - Sources of Harmonics in Distribution Systems and Ill Effects .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 l, SSSC and its Control, Sub-Synchronous Resonance Transient and Dynamic Stability Improvement in Power Systems - Converters for Static Compensation . Standard Modulation Strategies -GTO Inverters . Multi-Level Inverters)-Passive Harmonic Filtering. Single Phase Shunt Filter and its Control, Three Phase Active Filtering and their control 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.

EE6323: Digital Simulation of Power Electronic Systems

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

Principles of Modeling Power Semiconductor Devices - Macromodels versus Micromodels - Modelling ofControl Circuits for Power Electronic Switches. Computer - Review of Graph Theory as applied to Electrical Networks - Circuit Analysis Software MicroSimPSpice A/D - Statistical Analyses - Simulation

Examples of Power Electronic systems.-MicroSimPSpice A/D - MATLAB SIMULINK in Power system.Design Creation and Simulation with SaberDesigner - Analysing waveforms with SaberScope

EE6324: Advanced Control of PWM Inverter Fed induction Motors

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

Principles for vector and field-oriented control-Complex-valued dq-model - Dynamic model of IM in rotorfluxcoordinates. Methods to estimation of rotor-flux Generalized flux-vector control using current-andvoltage decoupling networks- Voltage-fed vector control. Stator-flux oriented vector control. Parametersensitivity, selection of flux level, and field weakening - Control strategies for used in the over-speedregion .Principles for speed sensor-less control - Principles for speed sensor-less control. Sensor-lessmethods for scalar control. Sensor-less methods for vector control .-Introduction to observer-based techniques

EE6325: Switched Mode and Resonant Converters

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

Buck, Boost, Buck-Boost SMPS Topologies .design relations - voltage mode control principles.Push-Pull and Forward Converter Topologies - Transformer Design -Output Filter Design - Half and Full Bridge Converters .FlybackConverter . Design Relations. Voltage Mode Control of SMPS . Stability Considerations . Study of popular PWM Control Ics (SG 3525,TL 494,MC34060 etc.)Current Mode Control of SMPS Study of a typical Current Mode PWM Control IC UC3842.Modeling of SMPS . State Space Averaging and Linearisation . The DC Transformer .General Control Law Considerations . Source toState Transfer Function . Source to Output Transfer Function .Stability . Loop Compensation EMI Generation and Filtering in SMPS - Power Circuit Layout for minimum EMI . EMI Filtering at Input and Output . Effect of EMI Filter on SMPS Control Dynamics-Introduction to Resonant Converters .. ResonantDC Link Inverters High Frequency Link Integral Half Cycle Converter.

EE6327: Linear and Digital Electronics

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

BJT and MOSFET Differential amplifiers and their analysis, Properties of ideal Opamps, Dominant polecompensation – internal and external compensation. The IOA model of an Opamp, analysis and design ofstandard linear applications of Opamps Sinusoidal oscillators using Opamps Active filtering – Butterworthlow pass filter functions –- Sallen and Key second order LP section Butterworth high pass filters –-multiple feedback single OPAMP LPF, HPF and BPF – State variable active filter, RegenerativeComparators, Monostable and Astable using Opamps, PLL and applications.
Time division multipliers - Analog switches - sample and hold amplifier – D/A conversion - successive approximation ADC - Basic digital circuits: Arithmetic Circuits, multiplexers and demultiplexers, decoders and encoders. Combinational circuit design using Multiplexer, ROM, PAL, PLA.
Design and analysis of sequential circuits: Analysis and design of Synchronous sequential Finite Sate Machine –Counters-Ripple Counters – Ring Counters – Shift registers counter design. Asynchronous sequential logic: Analysis and Design

EE6102: Optimal and Adaptive Control

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs.

Optimal control problem –- fundamental concepts and theorems of calculus of variations – Euler - Language equation and extremal of functionals - the variational approach to solving optimal control problems - Hamiltonian and different boundary conditions for optimal control problem – linear regulator problem - Pontryagin’s minimum principle - dynamic programming - principle of optimality and its application to optimal control problem - Hamilton-Jacobi-Bellman equation - model reference adaptive systems (MRAS) - design hypothesis - introduction to design method based on the use of Liapunov function – design and simulation of variable structure adaptive model following control

EE6121: Data Acquisition & Signal Conditioning

ELECTIVE COURSE

L	T	P	C
3	0	0	3

Pre-requisite: Nil

Total hours: 42 Hrs.

Data Acquisition Systems(DAS) - Objectives - General configurations - Transducers - Signal Conditioning - Instrumentation amplifiers - Noise Reduction Techniques in Signal Conditioning- Transmitters -Piezoelectric Couplers- Nyquist’s Sampling Theorem- classification and types of filters - Design of Filters- Butterworth Approximation-Narrow Bandpass and Notch Filters and their application inDAS-Analog-to-Digital Converters(ADC)-Multiplexers and demultiplexers -Digital-to-Analog

Conversion(DAC)- Data transmission systems- Modulation techniques and systems-Telemetry systems-Study of a representative DAS Board-Interfacing issues with DAS Boards- Software Drivers, Virtual Instruments, Modular Programming Techniques-Bus standard for communication between instruments -Software Design Strategies for DAS.

EE6122: Biomedical Instrumentation

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs.

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

EE6125: Digital Control Systems

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

Data conversion and quantisation- z transform and inverse z transform - Difference equation - Solution by recursion and z-transform- Discretisation Methods- z transform analysis of closed loop and open loop systems- Modified z- transfer function- Multirate z-transform- Stability of linear digital control systems-Steady state error analysis- Root loci - Frequency domain analysis- Digital controller design using bilineartransformation- Root locus based design- Digital PID controllers- Dead beat control design- Case studyexamples using MATLAB- State variable models- Controllability and Observability - Response betweensampling instants using state variable approach-Pole placement using state feedback – Servo Design- Statefeedback with Integral Control-Deadbeat Control by state feedback and deadbeat observers-Dynamicoutput feedback- Effects of finite wordlength on controllability and closed loop pole placement-Case studyexamples using MATLAB.

EE6129: Artificial Neural Networks and Fuzzy Systems

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

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

EE6204: Digital Protection of Power Systems

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs.

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

EE6222: Power Quality

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs.

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

EE6401: Energy Auditing & Management

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

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

EE6402: Process Control & Automation

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

Process Modeling, Transfer function-State space models-Time series models, Feedback &Feedforward Control, PID design and tuning, Cascade control- Selective control loops-Ratio control-Control, State feedback control- LQR problem- Pole placement, Process Interactions-Singular value analysis-tuning of multi loop PID control systems-decoupling control, Real-time optimization, Model predictive control-Batch Process control-Plant-wide control & monitoring, Introduction to Fuzzy Logic in Process Control, Introduction to OPC, Comparison of performance different types of control with examples on software packages

EE6403: Computer Controlled Systems

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

Multivariable control, Singular values- Stability norms, Robustness- Robust stability- H2 / H∞ Theory, Interaction and decoupling- Relative gain analysis, Decoupling control, Programmable logic controllers, SCADA, DCS, Real time systems, Supervisory control- direct digital control- Distributed control- PC based automation.

EE6404: Industrial Load Modeling& Control

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

Load Management, Load Modeling; Electricity pricing, Direct load control- Interruptible load control, Load scheduling- Continuous and Batch processes, Computer methods of optimization, -Reactive power control in industries- Cooling and heating load profiling, Energy Storage devices and limitations, Captive power units- Operating strategies- Power Pooling, Integrated Load management for Industries; Software packages-Case study.

EE6406: Industrial Instrumentation

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

Industrial measurement systems, sensors and transducers for different industrial variables, Amplifiers – Filters – A/D converters for industrial measurements systems, Calibration and response of industrial instrumentation, Generalized performance characteristics – static response characterization – dynamic response characterization, Response to different forcing functions such as step, sinusoidal etc. to zero, first,second third and higher orders of systems, Regulators and power supplies for industrial instrumentation,Servo drives, stepper motor drives types and characteristics, hybrid and permanent magnet motors.Advanced modeling tools and their characteristics for automated control instrumentation application

EE6421: Advanced Microcontroller Based Systems

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

Basic Computer Organization, Assembly Language Programming, Stack and Subroutines. Interrupts, DMA, Intel 8051, PIC 16F877, Digital Signal Processor (DSP) - Architecture – Programming, Microcontroller development for motor control applications, stepper motor control using micro controller

EE6422: Engineering Optimization

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

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

EE6424: Robotics Systems and Applications

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

Mathematics of Spatial Descriptions and Transformations-Robot definition, Robot classification. Robotic system components, Different orientation descriptions, Manipulator Kinematics and Mechanics of Robot Motion, Velocity Transformations, Static Forces Transformations, Manipulator Dynamics, Trajectory Planning, Inverse dynamics control, Robot controller architectures, Robot Sensing and Vision Systems, Introduction to Intelligent Robots, Robots in manufacturing automation

EE6426: Distribution Systems Management and Automation

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

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

EE6428: SCADA Systems and Applications

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 Hrs

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

DETAILED SYLLABUS

MA6003: MATHEMATICAL METHODS FOR POWER ENGINEERING
REQUIRED COURSE

L	T	P	C
3	**0**	**0**	**3**

Pre-requisite: Nil

Course outcomes:

CO1: Acquire knowledge about vector spaces, linear transformation, eigenvalues and eigenvectors of linear operators.
CO2: To learn about linear programming problems and understanding the simplex method for solving linear programming problems in various fields of science and technology.
CO3: Acquire knowledge about nonlinear programming and various techniques used for solving constrained and unconstrained nonlinear programming problems.
CO4: Understanding the concept of random variables, functions of random variable and their probability distribution.
CO5: Acquire knowledge about stochastic processes and their classification.

Total hours: 42 Hrs.

Module 1: **Linear Algebra** **(10 hours)**

Vector spaces, subspaces, Linear dependence, Basis and Dimension, Linear transformations, Kernels and Images , Matrix representation of linear transformation, Change of basis, Eigen values and Eigen vectors of linear operator

Module 2: Optimisation Methods I **(11 hours)**

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

Module 3: Optimisation Methods II **(10 hours)**

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

Module 4: Operations on Random Variables (11 hours)

Random Variables, Distributions and Density functions, Moments and Moment generating function, Independent Random Variables, Marginal and Conditional distributions, Conditional Expectation, Elements of stochastic processes, Classification of general stochastic processes.

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

EE6301: POWER ELECTRONIC CIRCUITS

REQUIRED COURSE

Pre-requisite: Nil

Total hours: 42 Hrs.

L	T	P	C
3	0	0	3

Course outcomes:

CO1: Acquire knowledge about analysis and design of various types of DC Chopper circuits

CO2: Acquire knowledge about harmonic analysis and filter circuit design of uncontrolled rectifiers

CO3: Acquire knowledge about various types of controlled rectifiers

CO4: Acquire knowledge about various PWM techniques of 2-level DC to AC converters

CO5: Acquire knowledge about analysis of multilevel inverters with advanced PWM techniques.

Module 1 **(11 hours)**

D.C.chopper circuits, Type-A, B, C, D and E configurations, Analysis of Type-A chopper with R-L load. Voltage and current commutated ChoppersLine Frequency Diode Rectifiers . Single-Phase Diode Bridge Rectifiers with Capacitor Filter . VoltageDoublerRectifiers . Effect of Single Phase Rectifiers on Neutral Currents in a Three Phase Four-WireSystem.

Three Phase half wave rectifier with resistive load . Three phase full wave rectifier . Double Y type rectifier. Single Phase rectifiers with LC filter . LC Filter Design. Three Phase Rectifier Circuits. Input LineCurrent Harmonics and power factor.

Module 2 **(10 hours)**

Line Frequency Phase-Controlled Rectifiers and Inverters .Single Phase - Half Wave Controlled Rectifierwith R , RL , RL with Flywheel diode loads . Full Wave Controlled Rectifier with various kinds of loads .Half Controlled and Full Controlled Bridges with passive and active loads - Input Line Current Harmonicsand Power Factor- Inverter Mode of Operation - Three Phase . Half Wave Controlled rectifier with RLLoad . Half Controlled Bridge with RL Load . Fully Controlled Bridge with RL Load . Input Side

CurrentHarmonics and Power Factor - Dual Converters . Circulating Current Mode and Non-Circulating CurrentMode .

Module 3 **(10 hours)**

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

Module 4 **(11 hours)**

Converters for Static Compensation . Standard Modulation Strategies - Programmed Harmonic Elimination . Multi-Pulse Converters and Interface Magnetics . Multi-Level Inverters of Diode ClampedType and Flying Capacitor Type and suitable modulation strategies -Space Vector Modulation – Minimumripple current PWM method. Multi-level inverters of Cascade Type. Current Regulated Inverter –CurrentRegulated PWM Voltage Source Inverters . Methods of Current Control . Hysteresis Control . VariableBand Hysteresis Control . Fixed Switching Frequency Current Control Methods . Switching Frequency Vsaccuracy of Current Regulation Areas of application of Current Regulated VSI .

Textbooks and References:

1.Ned Mohan et.al "Power electronics : converters, applications, and design" John Wiley and Sons, 2006

2.P.C. Sen "Power Electronics" Tata McGraw Hill, 2003.

3.G.K.Dubey et.al "Thyristorised Power Controllers" Wiley Eastern Ltd., 2005

4.Dewan&Straughen "Power Semiconductor Circuits" John Wiley &Sons., 1975 .

5.M.D.Singh&K.B.Khanchandani "Power Electronics" Tata McGraw Hill., 2007

6.B. K Bose Modern Power Electronics and AC Drives. Pearson Education (Asia)., 2007,09

EE6303: DYNAMICS OF ELECTRICAL MACHINES

REQUIRED COURSE

L	T	P	C
3	0	0	3

Pre-requisite: Nil

Total hours: 42 Hrs.

Course outcomes:

CO1: Formulation of electrodynamics equations of all electric machines and analyzes the performance characteristics.

CO2: Knowledge of transformations for the dynamic analysis of machines.

CO3: Knowledge of the determination of stability of the machines under small signal and transient conditions

Module 1 **(12 hours)**

Electro dynamical Equations and their Solution . A Spring and Plunger System- Rotational Motion System. Mutually Coupled Coils .Lagrange.sEquation . Application of Lagrange.s Equation to ElectromechanicalSystems . Solution of Electrodynamical Equations by Euler.s method and Runge-Kuttamethod .

Linearisation of the Dynamic Equations and Small Signal Stability . Differential Equations of a smooth airgaptwo winding machine . A two phase machine with current excitation - Interpretation of the AveragePower Conversion Conditions in terms of air-gap Magnetic Fields. The Primitive 4 Winding CommutaorMachine- The Commutator Primitive Machine . The Brush Axis and its Significance . Self and Mutuallyinduced voltages in the stationary and commutatorwindings . Speed e.m.f induced in CommutatorWinding. Rotational Inductance Coefficients . Sign of Speed e.m.f terms in the Voltage Equation . The CompleteVoltage Equation of Primitive 4 Winding CommutatorMachine . The Torque Equation . Analysis ofSimple DC Machines using the Primitive Machine Equations.

Module 2 **(11 hours)**

The Three Phase Induction Motor . Equivalent Two Phase Machine by m.m.fequivalence .equivalent twophase 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 Framesfor Induction Motor Analysis . Nonlinearities in Machine Equations . Equations under Steady State -Solution of Large Signal Transients in an Induction Machine .Linearised Equations of Induction Machine .

Small Signal Stability . Eigen Values . Transfer Function Formulation.

Module 3 **(10 hours)**

The Three Phase Salient Pole Synchronous Machine . Three Phase to Two Phase Transformation . Voltageand Torque Equations in stator, rotor and air-gap field reference frames .CommutatorTransformation andTransformed Equations . Parks Transformation . Suitability of Reference Frame Vs kind of Analysis to beCarried out . Steady State Analysis . Large Signal Transient Analysis .Linearisation and Eigen ValueAnalysis . General Equations for Small Oscillations . Small Oscillation Equations in State Variable form .

Damping and Synchronizing Torques in Small Oscillation Stability Analysis . Application of Small Oscillation Models in Power System Dynamics.

Module 4 **(9 hours)**

Dynamical Analysis of Interconnected Machines . Machine Interconnection Matrices . Transformation ofVoltage and Torque Equations using Interconnection Matrix . Large Signal Transient Analysis usingTransformed Equations . Small Signal Model using Transformed Equations . The DC Generator/DC MotorSystem . The Alternator /Synchronous Motor System . The Ward-Leonard System . Hunting Analysis ofInterconnected Machines Selection of proper reference frames
for individual machines in an InterconnectedSystem

Text Books and 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

EE6391: POWER ELECTRONICS LAB

LABORATORY COURSE

L	T	P	C
0	0	3	2

Pre-requisites: Nil

Course Outcomes:

CO1: To familiarize with the simulation and analytical softwares.

CO2: Analyze simulation results and do effective documentation.

CO3: Developing skills for designing, simulating and developing hardwares for power electronic circuits.

CO4: Acquire expertise in usage of modern power electronic hardware and software tools.

Total Hours: 42 Hours

List of Experiments

1. MOSFET Characteristics
2. IGBT Characteristics
3. Fullwave Uncontrolled Rectifier With C-Filter
4. Fullwave Uncontrolled Rectifier With L-Filter
5. Fullwave Uncontrolled Rectifier With L-C Filter
6. Fullwave Uncontrolled Rectifier With Voltage Doublers
7. Fullwave Controlled Rectifier With C-Filter
8. Fullwave Controlled Rectifier With L-Filter
9. Fullwave Controlled Rectifier With L-C Filter

EE6302: ADVANCED POWER ELECTRONIC CIRCUITS

REQUIRED COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Acquire knowledge about analysis and design of Load Commutated CSI and PWM CSI

CO2: Acquire knowledge about analysis and design of series Inverters.

CO3: Acquire knowledge about analysis and design of Switched Mode Rectifiers and APFC

CO4: Acquire knowledge about analysis and design of isolated and nonisolated Switched Mode DC to DC Converters

CO5: Acquire knowledge about analysis and design of Resonant Converters

Total hours: 42 Hrs.

Module 1 **(8 hours)**

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

Module 2 **(12 hours)**

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

Module 3 **(10 hours)**

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

Module 4 **(12 hours)**

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

Textbooks and References:

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

EE6304: ADVANCED DIGITAL SIGNAL PROCESSING

REQUIRED COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Course outcomes:

CO1: Acquire knowledge about the time domain and frequency domain representations as well as analysis of discrete time signals and systems

CO2: Acquire knowledge about the design of techniques for IIR and FIR filters and their realization structures.

CO3: Acquire knowledge about the finite word length effects in implementation of digital filters.

CO4: Acquire knowledge about the various linear signal models and estimation of power spectrum of stationary random signals

CO5: Acquire knowledge about the design of optimum FIR and IIR filters.

Total hours: 42 Hrs

Module 1 Discrete Time Signals, Systems and Their Representations (10 hours)

Discrete time signals- Linear shift invariant systems- Stability and causality- Sampling of continuous timesignals- Discrete time Fourier transform- Discrete Fourier series- Discrete Fourier transform- Z-transform-Properties of different transforms- Linear convolution using DFT- Computation of DFT

Module 2Digital Filter Design and Realization Structures (10 hours)

Design of IIR digital filters from analog filters- Impulse invariance method and Bilinear transformationmethod- FIR filter design using window functions- Comparison of IIR and FIR digital filters- Basic IIR andFIR filter realization structures- Signal flow graph representations

Module 3Analysis of Finite Word-length Effects (12 hours)

Quantization process and errors- Coefficient quantisation effects in IIR and FIR filters- A/D conversionnoise- Arithmetic round-off errors- Dynamic range scaling- Overflow oscillations and zero input limitcycles in IIR filters

Module 4Statistical Signal Processing (12 hours)

Linear Signal Models . All pole, All zero and Pole-zero models .Power spectrum estimation- Spectral analysis of deterministic signals . Estimation of power spectrum of stationary random signals-Optimumlinear filters-Optimum signal estimation-Mean square error estimation-Optimum FIR and IIR filters

Textbooks and References :

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

EE6306: POWER ELECTRONIC DRIVES
REQUIRED COURSE

L	T	P	C
3	0	0	3

Pre-requisites: None

Course Outcomes:

CO1: Develop capability to choose a suitable Motor and Power Electronic Converter package from a description of drive requirement – involving load estimation, load cycle considerations, thermal aspects and motor-converter matching

CO2: To learn about various DC and AC machines used in drives.

CO3: Acquire detailed knowledge of Electrical Motor operation using Generalized machine theory.

CO4: To understand the working and design of various converters used in Electrical Drives.

Total hours: 42 Hrs

Module – 1 **(10 hours)**

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

Module – 2 **(11hours)**

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 **(12 hours)**

Induction Motor Drives - Basic Principle of operation of 3 phase motor - Equivalent circuit - MMF spaceharmonics 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 frequencyCSI drives - Comparison of variable frequency drives - Line frequency variable voltage drives - Soft startof induction motors - Speed control by static slip power recovery. - Vector control of 3 phase squirrel cagemotors - Principle of operation of vector control-

Module – 4 **(9 hours)**

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

Textbooks and References:

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

EE6308: FACTS AND CUSTOM POWER
REQUIRED COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Acquire knowledge about the fundamental principles of Passive and Active Reactive Power Compensation Schemes at Transmission and Distribution level in Power Systems.

CO2: To introduce the student to various Static VAr Compensation Schemes like Thyristor/GTO Controlled Reactive Power Systems, PWM_Inverter based Reactive Power Systems and their controls .

CO3: To develop analytical modeling skills needed for modeling and analysis of such Static VAr systems with a view towards Control Design

CO4: Acquire knowledge about the fundamental principles of Unified Power Flow Conditioner and Interline Power Flow Conditioner in Power Systems.

CO5: Introduce the student to various UPFC Systems, Converters used in them and their control.

CO6: To develop analytical modeling skills needed for modeling and analysis of UPFC systems with a view towards Control Design.

CO7: To introduce the student to various Custom Power Systems, Modeling of such systems and Control Design for them

Total hours: 42 Hrs

Module 1 **(10 hours)**

Power flow in Power Systems – Steady-state and dynamic problems in AC systems – Voltage regulationand reactive power flow control in Power Systems – control of dynamic power unbalances in PowerSystem - Power flow control -Constraints of maximum transmission line loading - Benefits of FACTSTransmission line compensation- Uncompensated line -shunt compensation - Series compensation –Phaseangle control.
Reactive power compensation – shunt and series compensation principles – 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: TSSC, SSSC -Static voltage and phase angle regulators - TCVR and TCPAROperationand Control -Applications.
Static series compensation – GCSC,TSSC, TCSC and Static synchronous series compensators and theircontrol . SSR and its damping

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 - Introduction to interline power flow controller. Modelling and analysis of FACTS Controllers – simulation of FACTS controllers

Module 4 **(10 Hours)**

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

Textbooks and References:

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

EE6394 SEMINAR

REQUIRED COURSE

L	T	P	C
0	**0**	**3**	**1**

Pre requisites: Nil

Course outcomes:

CO1: To 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: To identify promising new directions of various cutting edge technologies

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

CO4: To 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.

EE6392 MINI PROJECT

REQUIRED COURSE

L	T	P	C
0	0	3	1

Pre requisites: Nil

Course outcomes:

CO1: To enable theengineering post graduate studentto undertake individual mini research projects in the area of power electronics under the guidance of a regular faculty

CO2: To enable the post graduate student to develop a complete small design and implement the projects in a hardware prototype/experimental setup and obtain the experimental results.

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

CO4: To effectively communicate by making an oral presentation before an evaluation committee

The mini project can be analytical / simulation/design or and fabrication in any of the areas in 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.

EE7391 MAIN PROJECT -1

REQUIRED COURSE

L	T	P	C
0	**0**	**16**	**8**

Pre requisites: Nil

Course outcomes:

CO1: Provides an opportunity to pursue their interest in power electronics through design, research, theoretical and experimental approach.

CO2: To enable the students to identify a topic of interest and complete the preliminary work of undertaking case studies, data collection and feasibility studies.

CO3: Students get guidance to formulate and develop a design proposal and to effectively communicate the same.

CO4: To effectively communicate by making an oral presentation of the progress of work before an evaluation committee

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.

EE7392 MAIN PROJECT -2

REQUIRED COURSE

L	T	P	C
0	**0**	**24**	**12**

Pre requisites: Nil

Course outcomes:

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

CO2: To inculcate the ability to 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: To report the concept and detailed design solution and to 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.

EE6321: POWER SEMICONDUCTOR DEVICES AND MODELING

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Course outcomes:

CO1: To learn the basics of power semiconductor switches.

CO2: To understand the working of various types of converters and application of them.

CO3: To understand and design the drive circuits for various Power Semiconductor Switches.

CO4: To learn to model the converters and semiconductor switches.

CO5: To learn about the control of various power semiconductor switches.

Total hours: 42 Hrs

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 . SchottkyDiodes .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/dtlimitations . Turn off Transient . Turn off time andreapplied dv/dtlimitations . 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 . GTOTurn on Transient . GTO Turn off Transient . Minimum ON and OFF State times .Maximum ControllableAnode Current . Overcurrent protection of GTOs

Module 2 **(12 hours)**

Power BJTs . Basic Structure and I-V Characteristics . Breakdown Voltages and Control . SecondBreakdown 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 offprocess . Switching Characteristics . Resistive Switching Specifications . Clamped Inductive SwitchingSpecifications - Turn on Transient and di/dtlimitations . Turn off Transient . Turn off time . SwitchingLosses . Effect of Reverse Recovery Transients on Switching Stresses and Losses - dv/dtlimitations .

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

Insulated Gate Bipolar Transistors (IGBTs) . Basic Structure and Operation .Latch up IGBT SwitchingCharacteristics . Resistive Switching Specifications . Clamped Inductive Switching Specifications – IGBTTurn on Transient . IGBT Turn off Transient- Current Tailing - Ratings of MOSFETs. FBSOA andRBSOA Curves . Switching Losses - Minimum ON and OFF State times - Switching FrequencyCapability - Overcurrent protection of IGBTs . Short Circuit Protection .Snubber Requirements andSnubber Design.

Module 3 **(12 hours)**

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

Module 4 **(12 hours)**

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

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

Text Books and References:

1. Ned Mohan et.al ,"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

EE6322: STATIC VAR CONTROLLERS & HARMONIC FILTERING

ELECTIVE COURSE

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Course outcomes:

CO1: Acquire knowledge about the fundamental principles of Passive and Active Reactive Power Compensation Schemes at Transmission and Distribution level in Power Systems.

CO2: To introduce the student to various single phase and three-phase Static VAr Compensation Schemes and their controls .

CO3: To develop analytical modeling skills needed for modeling and analysis of such Static VAr systems with a view towards Control Design

CO4: Acquire knowledge about the fundamental principles of Passive and Active Harmonic Filtering in Power Systems.

CO5: Introduce the student to various single-phase and three-phase active harmonic filtering systems employing Current-regulated PWM VSI and their control.

CO6: To develop analytical modeling skills needed for modeling and analysis of such Active Harmonic Filtering systems with a vioptimaew towards Control Design.

Total hours: 42 Hrs

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 QulityIssues . Sags, Sweels, Unbalance, Flicker , Distortion , Current Harmonics - Sources of Harmonics in DistributionSystems and Ill Effects .

Module – 2 **(11hours)**

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

Module – 3 **(12 hours)**

Converters for Static Compensation . Single Phase and Three Phase Converters and Standard ModulationStrategies (Programmed Harmonic Elimination and SPWM) . GTO Inverters . Multi-Pulse Converters andInterface Magnetics . Multi-Level Inverters of Diode Clamped Type and Flying Capacitor Type andsuitable 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 PhaseThree-wire Shunt Active Filtering and their control using p-q theory and d-q modelling . Three-phase fourwireshunt active filters . Hybrid Filtering using Shunt Active Filters . Series Active Filtering in HarmonicCancellation Mode . Series Active Filtering in Harmonic Isolation Mode . Dynamic Voltage Restorer andits 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 et.al Power Electronics. John Wiley and Sons 2006

EE6323: DIGITAL SIMULATION OF POWER ELECTRONIC SYSTEMS
ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Course outcomes:

CO1: To develop mathematical model of power electronic switches and electrical machines.
CO2: To study software packages PSpice, Matlab Simulink &Saber for the simulation of Power Electronic Systems.
CO3: Develop capability to design and simulate power electronic systems using PSpice.
CO4: Develop capability to design and simulate power electronic systems using Matlab Simulink.
CO5: Develop capability to design and simulate power electronic systems using Saber

Total hours: 42 Hrs

Module 1 **(10 hours)**

Principles of Modeling Power Semiconductor Devices - Macromodels versus Micromodels– Thyristormodel - Semiconductor Device modelled as Resistance, Resistance-Inductance and Inductance-Resistance-Capacitance combination - Modelling of Electrical Machines - Modelling of Control Circuits for PowerElectronic Switches. Computer Formulation of Equations for Power Electronic Systems - Review of GraphTheory as applied to Electrical Networks - Systematic method of Formulating State

Equations – ComputerSolution of State Equations - Explicit Integration method - Implicit Integration method.

Module 2 **(10 Hours)**

Circuit Analysis Software MicroSimPSpice A/D - Simulation Overview - Creating and Preparing a Circuitfor Simulation - Simulating a Circuit with PSpice A/D - Displaying Simulation Results - PSpice A/DAnalyses - Simple Multi-run Analyses - Statistical Analyses - Simulation Examples of Power Electronicsystems.

Module 3 **(10 Hours)**

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

Module 4 **(12 Hours)**

Design Creation and Simulation with SaberDesigner - Placing the Parts - Editing the Symbol - Properties -Wiring the Schematic - Modifying Wire Attributes - Performing a Transient and DC Analysis – PlacingProbes in the Design - Performing AC Analysis and Invoking SaberScope - Analysing waveforms withSaberScope - Performing Measurements on a waveform - Varying a Parameter - Displaying the ParameterSweep Results - Measuring a Multi-Member Waveform - Simulation Examples of Power ElectronicSystems.

Text Books and References:

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

EE6324: ADVANCED CONTROL OF PWM INVERTER FED INDUCTION MOTORS

ELECTIVE COURSE

L	T	P	C
3	0	0	3

Pre-requisite: Nil

Course Outcome:

CO1: To develop dynamic model of induction machines different frames of reference.

CO2: To understand principles of field oriented (vector) control of induction machines.

CO3: Develop capability to analyze the effects of machine parameter variations on the performance of induction machine fed drives.

CO4: To understand the principles of sensor-less speed control of induction machines.

CO5: To design a vector controlled induction machine drive system

Total Hours: 42Hrs

Module 1 **(12 hours)**

Principles for vector and field-oriented control-Complex-valued dq-model of induction machines. Turnsratio and modified dq-models. Principles for field-oriented vector control of ac machines. Currentcontrollers in stationary and synchronous coordinates.
Rotor-flux oriented control of current-regulated induction machine - Dynamic model of IM in rotor-fluxcoordinates. Indirect rotor-flux oriented control of IM - Direct rotor-flux oriented control of IM.-Methodsto estimation of rotor-flux

Module 2 **(10 hours)**

Generalized flux-vector control using current- and voltage decoupling networks- Generalized flux-vectororiented control. Current and voltage decoupling networks. Airgap-oriented control. Voltage-fed vectorcontrol. Stator-flux oriented vector control.

Module 3 **(10 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 theover-speed region .

Module 4 **(10 hours)**

Principles for speed sensor-less control - Principles for speed sensor-less control. Sensor-less methods forscalar 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 Sensorless Control of AC Drives, in K. RajashekaraSensorless 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. 92100.
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. 263271

EE6325: SWITCHED MODE AND RESONANT CONVERTERS
ELECTIVE COURSE

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Course outcomes:

CO1: Acquire knowledge about the principles of operation of non-isolated and isolated hard-switched DC-DC converters

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

CO3: Acquire knowledge on magnetics in switched mode converters and design of high frequency inductors and transformers with a DC bias.

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

CO5: Introduce the student to large-signal modeling and small signal modeling of hard- Z switched converters, development of transfer functions and design of error amplifiers.

CO6: Introduce the student to transient control in hard-switched converters by use of proper wiring practices, judicious component selection and various snubbers.

CO7: Introduce the student to resonant mode converters and their operation and control.

Total Hours: 42 Hours

Module 1 **(11 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 Problemand Solutions - Transformer Design -Output Filter Design -Switching Stresses and Losses – ForwardConverter 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.

FlybackConverter .discontinuous mode operation . waveforms .Control . Magnetics- Switching Stressesand Losses . Disadvantages - Continuous Mode Operation .Waveforms .Control . Design Relations

Module 2 **(10 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 popularPWM 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 ICUC3842.

Module 3 **(10 hours)**

Modeling of SMPS . State Space Averaging and Linearisation . State Space Averaging Approximation forContinuity . Discontinuous Conduction Modes . Small Signal Approximation- General Second OrderLinear Equivalent Circuits . The DC Transformer . Voltage Mode SMPS Transfer Function . GeneralControl 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 CircuitLayout for minimum EMI . EMI Filtering at Input and Output . Effect of EMI Filter on SMPS ControlDynamics

Module 4: **(11 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 LinkIntegral Half Cycle Converter.

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 et.al,PowerElectronics.,John Wiley and Sons 2006

4. OtmarKilgenstein,"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

EE6327: LINEAR AND DIGITAL ELECTRONICS

ELECTIVE COURSE

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Course outcomes:

CO1: To provide a detailed understanding of 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: To develop capability in designing various linear applications of opamps, various filters, sinusoidal oscillators etc., such that the student's design-preparedness to carry out projects in Power Electronics will be enhanced.

CO3: To develop capability in designing various nonlinear applications of opamps and comparators such as regenerative comparators, waveform generators, precision rectifiers, log-antilog amps etc., such that the student's design-preparedness to carry out projects in Power Electronics will be enhanced.

CO4: To develop capability in designing with VCOs, VFCs, FVCs, PLLs, ADCs, DACs, IC Multipliers/Dividers, OTAs etc., such that the student's design-preparedness to carry out projects in Power Electronics will be enhanced.

CO5: To develop design capability in designing combinational digital circuits using MUX, ROM, PLA, PAL etc., such that the students will be better prepared to carry out projects in Power Electronics will be enhanced.

CO6: To develop design capability in designing synchronous and asynchronous sequential digital circuits such that the students' design-preparedness to carry out projects in Power Electronics will be enhanced.

Total Hours: 42 Hours

Module 1 **(15 Hours)**

BJT and MOSFET Differential amplifiers and their analysis, Offset behaviour, Current sources for biasinginside a BJT/MOS IC –Properties of ideal Opamps, Internal description of a BJT Opamp, slew rate, internal description of a twostageMOS 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 ofstandard linear applications of OpampsReference diodes and voltage references, linear voltage regulatorsSinusoidal oscillators using Opamps

Active filtering – Butterworth low pass filter functions - low pass filter specifications - Order and cut offfrequency 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, HPFand BPFState variable active filter, Universal active filter.

Module 2 **(8 Hours)**

Regenerative Comparators, Comparator ICs , Square-Triangle – ramp generation, sine wave shaping,

Function generator ICs , VCO Circuits, VFCs and FVCs and applications, Monostable and Astable usingOpamps, PLL and applications.

Precision rectification, Log and Anti-log amplifiers, IC multipliers, Transconductance multiplier/divider,Time division multipliers

Analog switches - sample and hold amplifier –Data conversion fundamentals - D/A conversion – weighedresistor 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 usingKarnaugh map - Boolean function implementation. . Examples of useful digital circuits:

ArithmeticCircuits, Comparators and parity generators, multiplexers and demultiplexers, 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 **(10 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 anddesign 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, 2001

EE6102: OPTIMAL AND ADAPTIVE CONTROL

ELECTIVE COURSE

L	T	P	C
3	0	0	3

Pre-requisites: Nil

Course outcomes:

CO1: Acquire knowledge in the mathematical area of ‘calculus of variation’ so as to apply the same for solving optimal control problems.

CO2: Acquire knowledge of problem formulation, performance measure and mathematical treatment of optimal control problems so as to apply the same to engineering control problems with the possibility to do further research in this area.

CO3: Acquire knowledge on solving optimal control design problems by taking into consideration the physical constraints on practical control systems.

CO4: Acquire knowledge to obtain optimal solutions to controller design problems taking into consideration the limitation on control energy in the real practical world.

CO5: Acquire knowledge to develop and utilize modern software tools for design and analysis of optimal control problems.

CO6: Acquire knowledge in model reference adaptive control system design and to extend this knowledge to other areas of model following control with the idea of pursuing research in this area.

Total hours: 42 Hrs.

Module 1: (12 hours)

Optimal control problem – open loop and closed loop form of optimal control- performance measures for optimal control problems – general form of performance measure - fundamental concepts and theorems of calculus of variations – function and functional – Extremal of functionals of a single function - Euler - Language equation and solution- extremal of functionals of several independent functions – various boundary condition equations - piecewise-smooth extremals - extremal of functionals with dependent functions – use of Lagrange multipliers - differential equation constraints – isoperimetric constraints.

Module 2: (10 hours)

The variational approach to solving optimal control problems - necessary conditions for optimal control using Hamiltonian – Different boundary condition equations for solving the optimal control problem – closed loop control for linear regulator problem - linear tracking problem – Pontryagin’s minimum principle - state inequality constraints - minimum time problems - minimum control effort problems.

Module 3: (10 hours)

Dynamic programming - principle of optimality - application to multi stage decision making – application to optimal control problem – need for interpolation - recurrence relation of dynamic programming – curse of dimensionality - discrete linear regulator problem - Hamilton-Jacobi-Bellman equation – continuous linear regulator problem.

Module 4: (10 hours)

Model Reference Adaptive systems (MRAS) - the need for MRAS - an over view of adaptive control systems - mathematical description of MRAS - design hypothesis - equivalent representation of MRAS - introduction to design method based on the use of Liapunov function – design and simulation of variable structure adaptive model following control

Text Books and References:

1. Donald E. Kirk, Optimal Control Theory, An introduction, Prentice Hall Inc., 2004
2. A.P. Sage, Optimum Systems Control, Prentice Hall, 1977
3. HSU and Meyer , Modern Control, Principles and Applications, McGraw Hill, 1968
4. Yoan D. Landu, Adaptive Control (Model Reference Approach), Marcel Dekker. 1981
5. K.K.D.Young, Design of Variable Structure Model Following Control Systems., IEEE Transactions on Automatic Control, Vol. 23, pp 1079-1085, 1978.
6. A.S.I. Zinobar, O.M.E. EI-Ghezawi and S.A. Billings, Multivariable variable structure adaptivemodel following control systems. . Proc. IEE., Vol. 129, Pt.D., No.1, pp 6-12, 1982

EE6121 DATA ACQUISITION & SIGNAL CONDITIONING

ELECTIVE COURSE

L	T	P	C
3	0	0	3

Pre-requisites: Nil

Course outcomes:

CO1: Understand the objectives and configurations of data acquisition systems
CO2: Learn the working and characteristics of transducers
CO3: Learn about signal conditioning systems and noise reduction techniques
CO4: Acquire knowledge on filtering & sampling techniques and filter design
CO5: Acquire knowledge on signal conversion (analog to digital and digital to analog) techniques
CO6: Understand various data transmission techniques

CO7: Learn various interfacing techniques and standards for communication between instruments

Total hours: 42 Hrs.

Module 1: Transducers & Signal Conditioning (11 hours)

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

Module 2: Filtering and Sampling (10 hours)

Review of Nyquist.s Sampling Theorem- Aliasing . Need for Prefiltering-First and second order filters - classification and types of filters - Low -pass, High-pass, Band-pass and Band-rejection and All Pass: Butterworth, Bessel, Chebyshev and Elliptic filters .Opamp RC Circuits for Second Order Sections-Design of Higher Order Filters using second order sections using Butterworth Approximation-Narrow Bandpass and Notch Filters and their application in DAS. Sample and Hold Amplifiers Module 3: Signal Conversion and Transmission (10 hours) Analog-to-Digital Converters(ADC)-Multiplexers and demultiplexers - Digital multiplexer . A/D Conversion . Conversion Processes , Speed, Quantization Errors . Successive Approximation ADC . Dual Slope ADC . Flash ADC . Digital-to-Analog Conversion(DAC) . Techniques, Speed, Conversion Errors, Post Filtering- Weighted Resistor, R-2R, Weighted Current type of DACs- Multiplying Type DAC-Bipolar DACs- Data transmission systems-Schmitt Trigger-Pulse code formats- Modulation techniques and systems-Telemetry systems.

Module 3: Signal Conversion and Transmission (10 hours)

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

Module 4: Digital Signal Transmission And Interfacing (11 hours)

DAS Boards-Introduction . Study of a representative DAS Board-Interfacing Issues with DAS Boards, I/O vs Memory Addressing, Software Drivers, Virtual Instruments, Modular Programming Techniques for Robust Systems, Bus standard for communication between instruments - GPIB (IEEE-488bus) - RS-

232CUSB-4-to-20mA current loop serial communication systems.Communication via parallel port . Interruptbased Data Acquisition.Software Design Strategies-Hardware Vs Software Interrupts-Foreground/ background Programming Techniques- Limitations of Polling . Circular Queues

Text Books and 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.JohnUffrenbeck, 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

EE6122: BIOMEDICAL INSTRUMENTATION

ELECTIVE COURSE

L	T	P	C
3	0	0	3

Pre-requisites: Nil

Course outcomes:

CO1: Provide the students with an insight into the physiological system of the body and also an understanding on the generation of various bioelectric signals like ECG, EEG and EMG, their characteristic features and concepts of transduction.
CO2: Provide the students with an understanding of the various techniques and clinical instruments available for the measurement of various physiological parameters.
CO3: Provide the students the fundamentals of medical instrumentation along with their working principle.

CO4: Equip the students with research potential so that the principles of engineering and basic sciences shall be applied to improve the existing design and make it more economical and biocompatible for the betterment of mankind.

Total hours: 42 Hrs.

Module 1: (12 hours)

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

Module 2: (10 hours)

Measurement of cardiac out put – indicator dilution method – ultrasonic blood flow meter – electromagnetic blood flow meter – blood pressure measurement – oximetry – ear oximeter – pulse oximeter –skin reflectance oximeter -measurement on pulmonary system – spirometry –pulmonary functionanalyzers –ventilators

Module 3: (10 hours)

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

Module 4: (10 hours)

Measurement of PH , PCO2 , PO2 - radiotherapy – Cobalt 60 machine – medical linear accelerator machine – audiometry - electrical safety in hospitals

Text Books and References:

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

EE6125 DIGITAL CONTROL SYSTEMS

ELECTIVE COURSE

L	T	P	C
3	0	0	3

Pre-requisites: Nil

Course outcomes:

CO1: Acquire knowledge about the modeling of Digital Control Systems
CO2: Acquire knowledge about analysis of digital control systems in the z-domain as well as state space domain
CO3: Acquire knowledge about classical techniques for design of digital controllers with case study examples using MATLAB

CO4: Acquire knowledge about techniques based on state-space for design of digital controllers with case study examples using MATLAB

CO5: Acquire knowledge about the finite wordlengtheffects on system performance.

Total Hours: 42

Module 1: Introduction to Digital Control systems (11 hours)

Data conversion and quantisation - Sampling process- Mathematical modeling- Data reconstruction and filtering of sampled signals- Hold devices- z transform and inverse z transform - Relationship between s-plane and z- plane- Difference equation - Solution by recursion and z-transform- Discretisation Methods

Module 2: Analysis of Digital Control Systems (10 hours)

Digital control systems- Pulse transfer function - z transform analysis of closed loop and open loop systems- Modified z- transfer function- Multirate z-transform - Stability of linear digital control systemsStability tests- Steady state error analysis- Root loci - Frequency domain analysis- Bode plots- Nyquist plots- Gain margin and phase margin.

Module 3: Classical Design of Digital Control Systems (10 hours)

Cascade and feedback compensation by continuous data controllers- Digital controllers-Design using bilinear transformation- Root locus based design- Digital PID controllers- Dead beat control design- Case study examples using MATLAB

Module 4: Advanced Design of Digital Control Systems (11 hours)

State variable models- Interrelations between z- transform models and state variable modelsControllability and Observability - Response between sampling instants using state variable approachPole placement using state feedback – Servo Design- State feedback with Integral Control- Deadbeat Control by state feedback and deadbeat observers- Dynamic output feedback- Effects of finite wordlength on controllability and closed loop pole placement- Case study examples using MATLAB.

Textbooks and References:

1.B.CKuo , 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

EE6129: ARTIFICIAL NEURAL NETWORKS AND FUZZY SYSTEMS

ELECTIVE COURSE

L	T	P	C
3	0	0	3

Pre-requisites: Nil

Course outcomes:

CO1: To introduce the basic model of an artificial neuron and its relationship to biological neurons.
CO2: Acquire knowledge about the learning methods and training of the artificial neural networks.
CO3:Attack problems like weather forecasting, finger print identification, and optical character recognition using ANN.
CO4: Control applications like system identification, Parameter optimization, feedback controller design etc.
CO5:To understand the fuzzy logic and develop fuzzy rule based systems and its applications.

Total hours: 42 Hrs.

Module 1: **(10 hours)**

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

Module 2: **(10 hours)**

Learning process . Supervised and unsupervised learning . Error-correction learning, Hebbian learning, Boltzmen learning, Single layer and multilayer perceptturs, Least mean square algorithm, Back propagation algorithm, Applications in forecasting and pattern recognition and other engineering problems.

Module 3: **(10 hours)**

Fuzzy sets . Fuzzy set operations . Properties, Membership functions, Fuzzy to crisp conversion . fuzzification and defuzzification methods, applications in engineering problems.

Module 4: **(12 hours)**

Fuzzy control systems . Introduction, simple fuzzy logic controllers with examples, special forms of fuzzy logic models, classical fuzzy control problems .inverter pendulum, image processing .home heating system . Adaptive fuzzy systems, hybrid systems.

Text Books and References:

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

EE6204: DIGITAL PROTECTION OF POWER SYSTEMS
ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: The student must be capable of demonstrating the difference betweenelectromechanical and digital relays, and he/she is also introduced to themathematical relationships and numerical techniques used in digitalprotection.

CO2: The student must know the basic working of instrument transformers andtheir selection for a specific protection scheme design.

CO3: The student must have a clear understanding of the different mechanisms ofcircuits breakers and their selection for each of protection scheme design.

CO4: The candidate must have an understanding of the concept of different typesof relay ,including differential relay, ohm relay , mho relay, directional relay,distance relay, reactions relay etc. and their selection for each protectionscheme design.

CO5: The candidate must be capable of designing different protection schemesincluding over current protection scheme, directional over current protectionscheme, differential protection scheme, distance protection scheme andprotection scheme for distributed generation especially renewable energysystem etc.

CO6: The student must understand the basic principles of power systemprotection coordination.

Total hours: 42 Hrs.

Module 1 **(8 hours)**

Protective Relaying - Qualities of relaying - Definitions - Codes- Standards; Characteristic Functions;Classification –analog-digital- numerical; schemes and design-factors affecting performance –zones anddegree of protection; faults-types and evaluation; Instrument transformers for protection.

Module 2 **(12 hours)**

Basic elements of digital protection –signal conditioning- conversion subsystems- relay units-sequencenetworks-fault sensing data processing units- FFT and Wavelet based algorithms: least square anddifferential equation based algorithms-travelling wave protection schemes;Relay Schematics and Analysis- Over Current Relay- Instantaneous/Inverse Time –IDMT Characteristics;Directional Relays; Differential Relays- Restraining Characteristics; Distance Relays: Types-Characteristics;

Module 3 **(14 hours)**

Protection of Power System Equipment - Generator, Transformer, Transmission Systems, Busbars, Motors;Pilotwire and Carrier Current Schemes;System grounding –ground faults and protection; Load shedding and frequency relaying; Out of steprelaying ; Re-closing and synchronizing.

Module 4 **(8 hours)**

Integrated and multifunction protection schemes -SCADA based protection systems- FTA; Testing ofRelays.

Textbooks and References:

1. A T John and A K Salman- Digital protection for power systems-IEE power series-15, Peter Peregrines Ltd,UK,1997
2. C.R. Mason, The art and science of protective relaying, John Wiley &sons, 2002 Donald Reimert, ,Protective relaying for power generation systems, Taylor & Francis-CRC press 2006
3. Gerhard Ziegler-Numerical distance protection, Siemens, 2nd ed, 2006
4. A.R.Warrington, Protective Relays, Vol .1&2, Chapman and Hall, 1973

5. T S.MadhavRao, Power system protection static relays with microprocessor applications, Tata McGraw Hill Publication, 1994
6. Power System Protection Vol. I, II , III&IV, The Institution Of Electrical Engineers, Electricity Association Services Ltd., 1995
7. Helmut Ungrad , Wilibald Winkler, AndrzejWiszniewski, Protection techniques in electrical energy systems, Marcel Dekker, Inc. 1995
8. Badri Ram , D.N. Vishwakarma, Power system protection and switch gear, Tata McGraw Hill, 2001
9. Blackburn, J. Lewis ,Protective Relaying, Principles and Applications, Marcel Dekker, Inc., 1986.
10. Anderson, P.M, Power System Protection,. McGraw-Hill, 1999
11. Singh L.P ,Digital Protection, Protective Relaying from Electromechanical to Microprocessor, John Wiley & Sons, 1994
12. Wright, A. and Christopoulos, C, Electrical Power System Protection,. Chapman & Hall, 1993,
13. Walter A. Elmore, J. L. Blackburn, Protective Relaying Theory and Applications, ABB T&D Co. Marcel Dekker, Inc. 2004
14. Arun G. Phadke, James S. Thorp, Computer Relaying for Power Systems, Marcel Dekker, Inc 2009Quantum Physics of atoms, Molecules, Solids, Nuclei and Particle, Robert Eisberg and Robert Resnick, 2nd Ed., John Wiley(2006) Solid state Devices, B. G. Streetman, 5th Ed., Pearson (2006)

EE6222: POWER QUALITY

ELECTIVE COURSE

L	T	P	C
3	**0**	**0**	**3**

Pre-requisites: Nil

Course outcomes:

CO1: To introduce the student to the power quality issues, measures and standards.

CO2: Acquireknowledgeabout the harmonics, harmonic introducing devices andeffect of harmonics on system equipment and loads

CO3: To develop analytical modeling skills needed for modeling and analysis of harmonics in networks and components

CO4: To introduce the student to active power factor correctionbased on static VAR compensators and its control techniques

CO5: To introduce the student to series and shunt active power filtering techniques for harmonic cancellation and isolation

CO6: Acquireknowledgeabout theNEC grounding requirements and solutions to grounding and wiring problems

Total hours: 42 Hrs.

Module 1: **(9 hours)**

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

Module 2: **(10 hours)**

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

Module 3: **(12 hours)**

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

Module 4: **(11 hours)**

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

Text Books and 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. IEEE and IEE Papers from Journals and Conference Records

EE6401 ENERGY AUDITING & MANAGEMENT

ELECTIVE COURSE

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Course outcomes:

CO1: Acquire the background required for engineers to meet the role of energymanagers and to acquire the skills and techniques required to implementenergy management.

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

CO3: Acquire knowledge about standard methodologies for measuring energy inthe workplace and energy audit instruments.

CO4: Acquire knowledge about energy efficient motors, load matching andselection of motors.

CO5: Acquire knowledge about reactive power management, capacitor sizingand degree of compensation.

CO6: Acquire knowledge about cogeneration - types and schemes, optimaloperation of cogeneration plants with case studies.

CO7: Acquire knowledge about variable frequency drives, soft starters, and eddycurrent drives.

CO8: Acquire knowledge about energy conservation in motors, pumps, fans,compressors, transformers, geysers, lighting schemes, air conditioning,refrigeration, cool storage.

CO9: Gain hands-on experiences by encouraging students to conduct a walkthrough audit in various industries.

Total Hours: 42 Hours

Module 1 **(12 Hours)**

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

Module 2 **(11 Hours)**

Electric motors-Energy efficient controls and starting efficiency-Motor Efficiency and Load Analysis-Energy efficient /high efficient Motors-Case study; Load Matching and selection of motors.
Variable speed drives; Pumps and Fans-Efficient Control strategies- Optimal selection and sizing -Optimaloperation and Storage; Case study

Module 3 **(11 Hours)**

Transformer Loading/Efficiency analysis, Feeder/cable loss evaluation, case study.
Reactive Power management-Capacitor Sizing-Degree of Compensation-Capacitor losses-Location-Placement-Maintenance, case study.
Peak Demand controls- Methodologies-Types of Industrial loads-Optimal Load scheduling-case study.
Lighting- Energy efficient light sources-Energy conservation in Lighting Schemes- Electronic ballast-Power quality issues-Luminaries, case study.

Module 4 **(11 Hours)**

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

Text Books and References:

1. Handbook on Energy Audit and Environment Management , Y P Abbi and Shashank Jain, TERI, 2006
2. Handbook of Energy Audits Albert Thumann, William J. Younger, Terry Niehus, 2009
3. Giovanni Petrecca, .Industrial Energy Management: Principles and Applications., The Kluwerinternational 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 inIndustrialfacilities., IEEE Inc, USA. 2008
9. Albert Thumann, P.W, -.Plant Engineers and Managers Guide to Energy Conservation.– SeventhEdition-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', DhanpatRai and Sons, New Delhi.1975
12. TripathyS.C.,'Electric Energy Utilization And Conservation', Tata McGraw Hill, 1991
13. NESCAP-Guide Book on Promotion of Sustainable Energy Consumption, 2004
14. IEEE Bronze Book, IEEE STD 739
15. IEEE Recommended Practices for Energy Management in Industrial and Commercial Facilities
16. Guide to Energy Management, Sixth Edition , Barney L. Capehart (Author), Wayne C. Turner(Author), William J. Kennedy, Fairmont Press; 6 edition (April 23, 2008)
17. Energy Efficiency Manual: for everyone who uses energy, pays for utilities, designs and builds, is interested in energy conservation and the environment, Donald R. Wulfinghoff, Energy Institute Press(March 2000)
18. Handbook of Energy Audits, Seventh Edition, Albert Thumann., William J. Younger, Fairmont Press; 7 edition (November 12, 2007)

EE6402: PROCESS CONTROL & AUTOMATION

ELECTIVE COURSE

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Course Outcomes:

CO1 Acquire knowledge about the process modelling, control and instrumentation.

CO2: Study the effect of applying advanced control strategies to improve the process control system when working as SISO system and MIMO system

CO3: Get proficiency in multi loop and multi variable Control Systems, effect of process and controller interactions and methods to eliminate these effects.

CO4: Study and design of modern control strategies such as DMC, MPC, MRAS etc. its plant wide design giving importance to hierarchical control
CO5: Application of modern control devices in real time systems as case study

Total Hours: 42 Hours

Module 1 **(10 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-Poleplacement -Simulation using softwares-Control system instrumentation-Control valves- Codes andstandards- Preparation of P& I Diagrams.

Module 3 **(11 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 loopinteractions-Real-time optimization-Simulation using software.

Module 4: **(11 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 inProcess Control-Introduction to OPC-Introduction to environmental issues and sustainable developmentrelating to process industries. Comparison of performance different types of control with examples onsoftwares.

Textbooks and 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 7 Sustainable Development, American Society of Civil Engineers, 1997.
6. Nisenfeld(Ed) batch 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 and Tuning (3rd Edition) McGrawHill Book Co, 1988.
9. B. Wayne Bequette, Process control: modeling, design, and simulation Prentice Hall PTR, 2003K. Krishnaswamy, Process Control, New Age International, 2007

EE6403 COMPUTER CONTROLLED SYSTEMS

ELECTIVE COURSE

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Study the scientific and mathematical principles and methodologies relevant to computer control of systems.

CO2: Study of fundamentals of PLC and its architecture.

CO3: Learn the PLC programming fundamentals, process logic and human machine interface.

CO4: Understand SCADA architecture and communication protocols.

CO5: Study DCS architecture and configuration.

CO6: Detailed analysis of case studies of PLC, SCADA and DCS.

CO7: Understand the specifications and design techniques in real time system analysis.

CO8: Study the inter task communication, synchronization and real time memory management.

Total : 42 Hrs

Module 1: Multivariable Control (12 hours)

Multivariable control- Basic expressions for MIMO systems- Singular values- Stability normsCalculation of system norms- Robustness- Robust stability- H 2 / H ∞ Theory- Solution for design using H 2 / 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 (10 hours)

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

Module 3: Large Scale Control System (12 hours)

SCADA: Introduction, SCADA Architecture, Different Commnication 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.

Textbooks and 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 Engineer.s 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. EfimRosenwasser, Bernhard P. Lampe, Multivariable computer-controlled systems: a transfer function approach, Springer, 2006

EE6404: INDUSTRIAL LOAD MODELLING & CONTROL

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Course outcomes:

CO1: Acquire knowledge about load control techniques in industries and itsapplication.

CO2: Acquire knowledge about different types of industrial processes andoptimize the process using tools like LINDO and LINGO.

CO3: Acquire knowledge about load management to reduce demand of electricityduring peak time.

CO4: Analyse and understand different energy saving opportunities in industries.

CO5: Acquire knowledge about reactive power control in industries and analysedifferent power factor improvement methods.

CO6: Learn mathematical modelling and profiling of various loads such as coolstorage, cooling and heating loads.

Total Hours: 42 Hours

Module 1 **(12 Hours)**

Electric Energy Scenario-Demand Side Management-Industrial Load Management; Load Curves-LoadShaping Objectives-Methodologies-Barriers; Classification of Industrial Loads- Continuous and Batchprocesses -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 **(10 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;

Textbooks and 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, NewDelhi, 1995.
7. Cogeneration as a means of pollution control and energy efficiency in Asia 2000. Guide book byUNESC 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 inIndustrial facilities., IEEE Inc, USA.
9. ASHRAE Handbooks-1997-2000, American Society of Heating, Refrigerating and Air-conditioning
10. Engineers Inc., Atlanta, GA.Richard E. Putman, industrial energy systems: analysis, optimization, and control, ASME Press, 2004

EE6406: INDUSTRIAL INSTRUMENTATION

ELECTIVE COURSE

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: To get basic knowledge about industrial measurement system and different elements involved in it.

CO2: Acquire knowledge about sensors and transducers for different industrial variables like torque, pressure, etc.

CO3: Acquire knowledge about signal conditional circuits like amplifiers, filters, ADC, etc. for working industrial measurement systems.

CO4: Impart knowledge about static and response characteristics of first order and higher order measurement system.

CO5: To get familiarize with the operation and applications in measurement systems of servo motors.

Total Hours: 42 Hours

Module 1 **(12 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 Industrialinstruments.

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 forcingfunctions such as step, sinusoidal etc. to zero, first, second third and higher orders of systems.

Module 3 **(12 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 **(10 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 – hybridstepper motor – permanent magnet stepper motor – hybrid and permanent magnet motors – single and multistep responses.

Textbooks and References :

1. Ernest O. Doebelin Measurement systems applications and design, McGraw – Hill InternationalEditions, McGraw- Hill Publishing Company, 1990
2. Patric F. Dunn University of Notre Dame, Measurement and Data Analysis for engineering and science,McGraw 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 ControlsHandbook,5th Edition, McGraw Hill 1999
7. Steve Mackay, Edwin Wright, John Park, Practical Data Communications for Instrumentation andControl, 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

EE6421 ADVANCED MICROCONTROLLER BASED SYSTEMS
ELECTIVE COURSE

L	T	P	C
3	0	0	3

Pre-requisites : Nil

Course Outcomes:

CO1: To understand the working of advanced microprocessor/controller.
CO2: To learn how to program a processor in assembly language and develop an advanced processor based system.
CO3: To learn configuring and using different peripherals in a digital system.
CO4: To compile and debug a Program.
CO5: To generate an executable file and use it.

Total Hours: 42 Hours

Module 1 **(10 Hours)**

Basic Computer Organization - Accumulator Based Processors - Architecture - Memory organizations - I/O Organizations - Assembly Language Programming - Addressing - Operations - Stack and Subroutines . Interrupts - DMA - Stages of Microprocessor based Program Development.

Module 2 **(12 Hours)**

Introduction to Microcontrollers - Motorola 68HC11 - Intel 8051 - Intel 8096 - Registers - Memories - I/OPorts - Serial Communications - Timers – Interrupts

Module 3 **(10 Hours)**

PIC 16F877- Architecture - Memory Interfacing - Interfacing I/O devices - Instruction Set - Serial I/O and Data Communication. Digital Signal Processor (DSP) - Architecture – Programming. Introduction to FPGA.

Module 4 **(10Hours)**

PIC 16F877- Architecture - Memory Interfacing - Interfacing I/O devices - Instruction Set - Serial I/O andDataCommunication.Digital Signal Processor (DSP) - Architecture – Programming.IntroductiontoFPGA.

Textbooks and References :

1. John.F.Wakerly: Microcomputer Architecture and Programming, John Wiley and Sons 1981

2. Ramesh S.Gaonker: Microprocessor Architecture, Programming and Applications with the 8085, Penram International Publishing (India), 1994
3. Raj Kamal: The Concepts and Features of Microcontrollers, Wheeler Publishing, 2005
4. Kenneth J. Ayala, The 8051 microcontroller, Cengage Learning, 2004
5. John Morton, The PIC microcontroller: your personal introductory course, Elsevier, 2005
6. Dogan Ibrahim, Advanced PIC microcontroller projects in C: from USB to RTOS with the PIC18F Series, Elsevier, 2008
7. Micro chip datasheets for PIC16F877

EE6422: ENGINEERING OPTIMIZATION

ELECTIVE COURSE

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Understand the concept of optimization and classical methods of optimization.

CO2: Apply optimization techniques to typical engineering problems.

CO3: Learn the concepts and techniques of nonlinear and unconstrained optimization.

CO4: Acquire knowledge on direct and indirect methods for constrained optimization.

CO5: Learn the application of dynamic programming and genetic algorithms for engineering optimization.

Total Hours : 42 Hours

Module 1 **(11 hours)**

Concepts of optimization: Engineering applications-Statement of optimization problem-Classification - type and size of the problem.

Classical Optimization Techniques: Single and multi variable problems-Types of Constraints .Semi definite case-saddle point.

Linear programming: Standard form-Geometry of LP problems-Theorem of LP-Relation to convexity - formulation of LP problems - simplex method and algorithm -Matrix form- two phase method.

Duality- dual simplex method- LU Decomposition. Sensitivity analysis .Artificial variables and complementary solutions-QP.

Engineering Applications: Minimum cost flow problem, Network problems-transportation, assignment & allocation, scheduling .Karmarkar method-unbalanced and routing problems.

Module 2 **(11 hours)**

Nonlinear programming: Non linearity concepts-convex and concave functions- non-linear programming -gradient and Hessian.

Unconstrained optimization: First & Second order necessary conditions-Minimisation&Maximisation-Local & Global convergence-Speed of convergence.

Basic decent methods: Fibonacci & Golden section search - Gradient methods - Newton Method-Lagrangemultiplier method - Kuhn-tucker conditions .Quasi-Newton method- separable convex programming -Frank and Wolfe method, Engineering Applications.

Module 3 **(10 hours)**

Nonlinear programming- Constrained optimization: Characteristics of constraints-Direct methods-

SLP,SQP-Indirect methods-Transformation techniques-penalty function-Langrange multiplier methodscheckingconvergence- Engineering applications.

Module 4 **(10 hours)**

Dynamic programming: Multistage decision process- Concept of sub optimization and principle ofoptimality- Computational procedure- Engineering applications.
Genetic algorithms- Simulated Annealing Methods-Optimization programming, tools and Softwarepackages.

Textbooks and 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. KKalyanmoy Deb,.Optimisation for Engineering Design-Algorithms and Examples., Prentice Hall India- 1998

EE6424 ROBOTIC SYSTEMS AND APPLICATIONS
ELECTIVE COURSE

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Learn the mathematics of spatial descriptions and transformations
CO2: Acquire knowledge about robot definition, classification, robot system components that combines embedded hardware, software and mechanical systems
CO3: Learn manipulator kinematics and mechanics of robot motion, forward and inverse kinematic transformation of position, forward and inverse kinematic transformation of velocity, end effector force transformations
CO4: Learn about manipulator dynamics, transformation of acceleration, trajectory planning, Lagrangian formulation, Newton-Euler equations of motion, robot control architectures
CO5: Acquire knowledge about robot sensing and vision systems
CO6: Acquire knowledge about robot programming languages
CO7: Acquire knowledge about artificial intelligence techniques in robotics
CO8: Learn about various robotics applications and their associated components and control systems in manufacturing, construction, service, etc.

Total Hours: 42
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: **(12 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: **(13 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.

Textbooks and 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.GrooverMikell 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

EE6426 DISTRIBUTION SYSTEMS MANAGEMENT & AUTOMATION
ELECTIVE COURSE

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Acquire knowledge about the fundamental principles, hierarchy level, architecture, functions and implementation strategies of Distribution Automation Systems (DAS) and Distribution Management Systems (DMS).

CO2: Acquire knowledge about the fundamental concept of different power quality issues and application of Custom power devices improving power quality and about the issues relating Integration of Distributed Generation (DG) and Custom Power components in a distribution system.

CO3: Acquire ability to evaluate the performance of electrical distribution system on the basis of reliability indices calculation.

CO4: Acquire knowledge about Electrical distribution system design aspects of industrial and commercial buildings with emphasis given to Electrical Safety and Earthing Practices.

CO5: Acquire knowledge about the wireless and wired communication systems, user interface, communication protocols and architectures for control and automation of Distribution system.

CO6: Acquire knowledge about the concept of deregulated power system.

Total hours: 42 Hrs

Module 1 **(10 hours)**

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

Module 2 **(10 hours)**

Electrical System Design: Distribution System Design- Electrical Design Aspects of Industrial,Commercials Buildings- Electrical Safety and Earthing Practices at various voltage levels- IS codes

Module 3 **(12 hours)**

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

Module 4: **(10Hours)**

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

Text Books and References:

1. James Northcote – Green, Robert Wilson, “Control and Automation of Electrical Power Distribution Systems”, CRC Press, New York, 2007.
2. TuranGonen: .Electric Power Distribution System Engineering. McGraw Hill Company. 1986
3. V Deshpande: .Electrical Power System Design. Tata-McGraw Hill, 1966
4. IEEE Press: IEEE Recommended practice for Electric Power Distribution for Industrial Plants, published by IEEE, Inc., 1993
5. Pansini, Electrical Distribution Engineering, The Fairmont Press, Inc., 2007
6. Pabla H S.: .Electrical Power Distribution Systems.. Tata McGraw Hill. 2004
7. IEEE Standerd739 . Recommended Practice for Energy Conservation and Cost Effective Planning in Industrial Facilities. 1984
8. G H Heydt .Electric Power Quality. McGram Hill, 2007
9. Wilson K. Kazibwe and Musoke H Semdaula .Electric Power Quality Control Techniques.. Van Nostarand Reinhold New York, 2006
10. Lakervi& E J Holmes .Electricity distribution network design., 2nd Edition Peter Peregrimus Ltd. York, 1993

EE6428: SCADA SYSTEMS AND APPLICATIONS

ELECTIVE COURSE

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Pre-requisites: Nil

Course outcomes:

CO1: Describe the basic tasks of Supervisory Control Systems (SCADA) as wellas their typical applications

CO2: Acquire knowledge about SCADA architecture, various advantages anddisadvantages of each system

CO3: Acquire knowledge about single unified standard architecture IEC 61850

CO4: Acquire knowledge about SCADA system components: remote terminalunits, PLCs, intelligent electronic devices, HMI systems, SCADA server

CO5: Acquire knowledge about SCADA communication, various industrialcommunication technologies, open standard communication protocols

CO6: Learn and understand about SCADA applications in transmission anddistribution sector, industries etc.

CO7: Gain knowledge and understanding for the design and implementation of aSCADA system

Number of Hours: 42Hrs

Module 1 **(10 hours)**

Introduction to SCADA**:** Data acquisition systems, Evolution of SCADA, Communication technologies,Monitoring and supervisory functions, SCADA applications in Utility Automation, Industries

Module 2 **(11 hours)**

SCADA System Components**:** Schemes- Remote Terminal Unit (RTU),Intelligent Electronic Devices(IED),Programmable Logic Controller (PLC), Communication Network, SCADA Server, SCADA/HMISystems

Module 3 **(11 hours)**

SCADA Architecture**: V**arious SCADA architectures, advantages and disadvantages of each system - single unified standard architecture **-**IEC 61850. SCADA Communication**:** various industrialcommunication technologies **-**wired and wireless methods and fiber optics. open standard communicationprotocols

Module 4 **(10 hours)**

SCADA Applications**:** Utility applications- Transmission and Distribution sector -operations, monitoring,analysis and improvement. Industries **-** oil, gas and water. Case studies, Implementation, SimulationExercises

Textbooks and 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