NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

SCHEME OF INSTRUCTION AND SYLLABI

FOR M.TECH POWER ELECTRONICS & DRIVES PROGRAM

Effective from 2016-17

DEPARTMENT OF ELECTRICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.

- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.

- Fostering product oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

DEPARTMENT OF ELECTRICAL ENGINEERING

VISION

To excel in education, research and technological services in electrical engineering in tune with societal aspirations.

MISSION

- Impart quality education to produce globally competent electrical engineers capable of extending technological services
- Engage in research & development in cutting edge and sustainable technologies.
- Nurture scientific temperament, professional ethics and industrial collaboration

GRADUATE ATTRIBUTES

The Graduate Attributes are the knowledge skills and attitudes which the students have at the time of graduation. These attributes are generic and are common to all engineering programs. These Graduate Attributes are identified by National Board of Accreditation.

1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. Problem analysis: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. Design/Development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.
6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. Project management and Finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

DEPARTMENT OF ELECTRICAL ENGINEERING

M.TECH IN POWER ELECTRONICS & DRIVES

PROGRAM EDUCATIONAL OBJECTIVES

PEO1.	Design and develop innovative products and services in the field of Power Electronics & Drives
PEO2.	Keep abreast with the latest technology and toolset.
PEO3.	Communicate effectively to propagate ideas and promote teamwork
PEO4.	Attain intellectual leadership skills to cater to the changing needs of power industry, academia, society and environment

Mapping of Mission statements with program educational objectives

Mission Statement	PEO1	PEO2	PEO3	PEO4
Impart quality education to produce globally competent electrical engineers capable of extending technological services	3	2	2	3
Engage in research & development in cutting edge and sustainable technologies.	2	1	3	2
Nurture scientific temperament, professional ethics and industrial collaboration.	3	1	1	3

Mapping of program educational objectives with graduate attributes

PEO	GA1	GA2	GA3	GA4	GA5	GA6	GA7	GA8	GA9	GA10	GA11	GA12
PEO1	3	3	3	2	3	2	2	1	2	1	3	3
PEO2	1	1	2	2	3	2	2	1	1	-	-	3
PEO3	-	-	-	-	-	1	-	-	3	3	2	2
PEO4	2	3	3	3	3	3	2	1	-	-	-	3

PROGRAM OUTCOMES: At the end of the program the student will be able to:

PO1	Design and develop power electronic circuits and drive systems
PO2	Deliver technological solutions in the field of power electronics and drives by assimilating advances in allied disciplines
PO3	Simulate and experiment in the field of power electronics and drives using modern tools
PO4	Design renewable energy systems to protect environment and ecosystems
PO5	Practice professional ethics with social sensitivity
PO6	Develop innovative and entrepreneurial solutions
PO7	Develop an attitude to learn with self-motivation
PO8	Communicate effectively at all levels and demonstrate leadership qualities
PO9	Pursue research to enhance the existing pool of knowledge

Mapping of program outcomes with program educational objectives

PO	PEO1	PEO2	PEO3	PEO4
1	3	2	1	3
2	3	2	1	3
3	3	2	1	3
4	3	2	2	3
5	-	-	2	2
6	3	-	2	3
7	1	3	1	1
8	1	-	3	2
9	3	3	2	3

SCHEME OF INSTRUCTION

M.TECH (POWER ELECTRONICS & DRIVES) Course Structure

M. Tech. I - Year I - Semester

S. No.	Course Code	Course Title	L	T	P	Credits
1	EE5101	Analysis of Power Converters	4	0	0	4
2	EE5102	Analysis and Modeling of Electrical Machines	4	0	0	4
3	EE5103	Applications of Digital Signal Processors	4	0	0	4
4	EE5104	Power Electronics Lab	0	0	3	2
5	EE5105	Digital Signal Processing Lab	0	0	3	2
6		Elective –I	3	0	0	3
7		Elective – II	3	0	0	3
8		Elective – III	3	0	0	3
9	EE5141	Seminar – I	0	0	2	1
		TOTAL	**21**	**0**	**8**	**26**

List of Electives:

MH5013 Optimization Techniques

EE5111 Modern Control Theory

EE5112 Control & Integration of Renewable Energy Sources

EE5113 Electromagnetic interference and compatibility

EE5114 Nonlinear Control Systems

EE5211 AI Techniques in Power Engineering

EE5214 Smart Grid Technologies

M.Tech. I - Year II - Semester

S. No.	Course Code	Course Title	L	T	P	Credits
1	EE5151	Advanced Power Electronics	4	0	0	4
2	EE5152	Advanced Electric Drives	4	0	0	4
3	EE5153	Digital Control Systems	4	0	0	4
4	EE5154	Electric Drives Lab	0	0	3	2
5	EE5155	Power Electronic Simulation Lab	0	0	3	2
6		Elective –IV	3	0	0	3
7		Elective – V	3	0	0	3
8		Elective – VI	3	0	0	3
9	EE5191	Seminar – II	0	0	2	1
		Total	**21**	**0**	**8**	**26**

List of Electives:

EE5161 Applications of Power Converters

EE5162 Modeling and Simulation of Power Electronic Systems

EE5163 Power Quality Improvement Techniques

EE5164 Electric Vehicles

EE5265 Energy Auditing and Management

EE5166 Digital Signal Processor Controlled Drives

EE5263 Flexible AC Transmission Systems

II - Year I - Semester

S. No.	Course Code	Course Title	L	T	P	Credits
1	EE6142	Comprehensive Viva-voce	0	0	0	2
2	EE 6149	Dissertation-Part-A	0	0	0	6
		Total	**-**	**-**	**-**	**8**

II - Year II - Semester

S. No.	Course Code	Course Title	L	T	P	Credits
1	EE 6199	Dissertation-Part-B	0	0	0	12
		Total				**12**

List of Electives

I Year I Semester

MH5013 Optimization Techniques

EE5111 Modern Control Theory

EE5112 Control & Integration of Renewable Energy Sources

EE5113 Electromagnetic interference and compatibility

EE5114 Nonlinear Control Systems

EE5211 AI Techniques in Power Engineering

EE5214 Smart Grid Technologies

I Year II Semester

EE5161 Applications of Power Converters

EE5162 Modeling and Simulation of Power Electronic Systems

EE5163 Power Quality Improvement Techniques

EE5164 Electric Vehicles

EE5265 Energy Auditing and Management

EE5166 Digital Signal Processor Controlled Drives

EE5263 Flexible AC Transmission Systems

DETAILED SYLLABUS

EE5101	Analysis of Power Converters		4 – 0 – 0	4 Credits

Course Outcomes:

CO1	Select an appropriate power semiconductor device and design a power converter for the required application
CO2	Determine the power circuit configurations to fulfill the required power conversion with applicable constraints
CO3	Design the control circuit and the power circuit for a given power converter
CO4	Design DC-DC converters, DC-AC inverters and front-end AC-DC converters

Overview of Switching Power Devices: Static and dynamic characteristics of switching devices: BJT- MOSFET- IGBT- GTO- GaN Design of driver and snubber circuit, Series and parallel operation of switching devices

DC-DC Converters: Non-isolated DC-DC converters: buck- boost- buck-boost, CUK converters under continuous and discontinuous conduction operation. Isolated DC-DC converters: forward- fly-back- push-pull- half-bridge- and full-bridge converters. Relationship between I/P and O/P voltages- expression for filter inductor and capacitors, High gain DC-DC converters.

Inverters: Single-phase and three-phase inverters- PWM techniques: single- multiple- and sinusoidal PWM techniques- selective harmonic elimination- space vector modulation- current source inverter- multi-level inverters- Diode-clamped, cascaded, and Flying capacitor types,concept of active Filters

Front-End (AC-DC) Converters: PWM rectifiers-configuration types, three-phase full and semi converters- reactive power- power factor improvements – extinction angle control- symmetrical angle control- PWM control

Text books:

1. M.H. Rashid **:**Power Electronics-circuits, Devices & Applications**,** 3rd ed.,PHI, 2005.
2. N Mohan, T.M. Undeland, WP.Robbins**:** Power Electronics: Converters, Applications**,** 3rd ed.,John Wiley & Sons, 2009.

References:

1. Umanand, L., Power Electronics: Essentials and Applications, chapters 1 to 7, John Wiley, India, 2009.
2. JayantBaliga B, Power Semiconductor Devices, PWS 1996.
3. Current literature

EE5102	Analysis and Modeling of Electrical Machines	4–0 – 0	4 Credits

Course Outcomes:

CO1	Develop models for linear and nonlinear magnetic circuits
CO2	Determine the developed torque in an electrical machine using the concepts of field Energy and co-energy and determine the dynamic model of a DC machine
CO3	Determine the dynamic model of an induction machine based on the dq0 Transformation and determine instantaneous torque developed in an induction Machine- which leads to advanced control strategies such as vector control and direct torque control
CO4	Determine the torque developed in a salient pole synchronous machine using the Park's transformation and identify contribution of saliency torque- damping torque and excitation torque

Basic Principles for Electrical Machine Analysis: Magnetically coupled circuits: review of basic concepts, magnetizing inductance, Modeling linear and nonlinear magnetic circuits, Electromechanical energy conversion: principles of energy flow, concept of field energy and coenergy, Derivation of torque expression for various machines using the principles of energy flow and the principle of coenergy, Inductance matrices of induction and synchronous machines.

DC Machines: Theory of DC machines: Review of the DC machine, model of a commutator, State-space model of a DC machine, reduced order model & transfer function of the DC machine

Reference Frame Theory: Concept of space vector, components of space vector, direct and quadrature axis variables, various types of transformation, condition for power invariance, Expression for power with various types of transformation, Transformations between reference frames, Clarke and Park's Transformations, Variables observed from various frames, Simulation studies

Theory of symmetrical Induction Machines: Voltage and torque in machine variables, Derivation of *dq0* model for a symmetrical induction machine, Voltage and torque equation in arbitrary reference frame variables, Analysis of steady- state operation, State-space model of induction machine in '*d-q'* variables, Simulation studies

Theory of synchronous machines: Equations in arbitrary reference frame, Park's transformation, Derivation of *dq0* model for a salient pole synchronous machine with damper windings, Torque expression of a salient pole synchronous machine with damper windings and identification of various components.

Text Books:

1. Paul C. Krause, Oleg W, Scott D. Sudhoff: "*Analysis of Electric Machinery & Drive systems*", IEEE Press, 2nd ed., 2002.
2. Rama Krishnan: Electric motor drives: modeling, analysis, and control, Prentice Hall, 2001.

Reference Books:

1. Rik De Doncker, Duco W. J. Pulle, André Veltman: Advanced Electrical Drives: Analysis, Modeling, Control Springer, 2011.
2. A. E.*Fitzgerald,* CharlesKingsley, Stephen D. Umans: Electric Machinery, TMH, 5th ed.

EE5103	Applications of Digital Signal Processors		4 – 0 – 0	4 Credits

Course Outcomes:

CO1	Write Assembly Language Programs for the Digital Signal Processors
CO2	Configure and use Digital Input / Output lines and ADCs
CO3	Configure and use Interrupts and Event Managers for PWM generation
CO4	Employ DSPs & FPGAs for the real time control of Power Electronic Controllers

Introduction to the TMSLF2407 DSP Controller: Brief Introduction to Peripherals - Types of Physical Memory - Software Tools

C2XX DSP CPU and instruction set: Introduction to the C2xx DSP Core and Code Generation - The Components of the C2xx DSP Core - Mapping External Devices to the C2xx Core and the Peripheral Interface -System Configuration Registers –Memory -Memory Addressing Modes - Assembly Programming Using the C2xx DSP Instruction Set

Parallel and Serial Data Transfer: Pin Multiplexing (MUX) and General Purpose I/O Overview - Multiplexing and General Purpose I/O Control Registers - Using the General Purpose I/O Ports, Serial Communication

Interrupt system of TMS320LF2407: Introduction to Interrupts - Interrupt Hierarchy - Interrupt Control Registers - Initializing and Servicing Interrupts in Software, real time control with interrupts

The analog-to-digital converter (ADC): ADC Overview - Operation of the ADC and programming modes

Event Managers (EVA, EVB): Overview of the Event Manager (EV) - Event Manager Interrupts - General Purpose (GP) Timers- Compare Units - Capture Units and Quadrature Encoded Pulse (QEP) Circuitry - General Event Manager Information - PWM Signal Generation with Event Managers and interrupts, Measurement of speed with Capture Units, Implementation of Space Vector Modulation with DSP TMSLF2407A

Field Programmable Gate Arrays: Introduction to Field Programmable Gate Arrays – CPLD Vs FPGA – Types of FPGA , Configurable logic Blocks (CLB), Input/Output Block (IOB) – Programmable Interconnect Point (PIP)- HDL programming –overview of Spartan 6 & ISE Design Suite, Implementation of PWM technique with SPARTAN-6 FPGA

Text Books:

1. Hamid A. Tolyat**, "**DSP based Electromechanical Motion Control**"-**CRC press, 2004.
2. Wayne Wolf,'FPGA based system design', Prentice hall, 2004.

Reference books:

1. Application Notes from the website of Texas Instruments
2. Spartan-6 FPGA Configurable Logic Block, 2010
3. Xilinx Spartan 6 Data sheets

EE5104	Power Electronics Lab		0–0–3	2Credits

Course Outcomes:

CO1	Design the control circuit and the power circuit for DC-DC converters
CO2	Verify the compliance of spectral performance of a Three-phase Voltage Source Inverter
CO3	Critically compare various options available for the control and drive circuit requirements
CO4	Recognize possible modes of failure of a circuit - troubleshoot and repair

Detailed syllabus

1. Experimental study for characteristics of DC-DC Buck converter.
2. Experimental study for characteristics of DC-DC Boost converter.
3. Experimental study for characteristics of DC-DC Buck-Boost converter
4. Control for DC-DC converters using DSP
5. Experimental study of PWM AC-DC converter
6. Experimental study for unipolar and bipolar PWM of a 1-phase Inverter
7. Quasi-square wave control of a 1-Ph Full bridge VSI
8. Study of a VCO based sine-triangle PWM controller for a 3-phase VSI
9. Implementation of SVM using DSP for a 3-phase VSI
10. Study of the effects of common-mode voltages for an SVM controlled 3-phase VSI
11. Evaluation of the Harmonic Performance of a 3-Ph, 2-level VSI using dSPACE system
12. Evaluation of the Harmonic Performance of a 3-Ph, NPC 3-level VSI
13. Study of Flyback Converters
14. Study of PV characteristics and Implementation of MPPT

EE5105	Digital Signal Processors Lab	0 – 0 – 3	2 Credits

Course Outcomes:

CO1	Configure the on-chip peripherals such as ADC, Digital I/O and QEP to suit the control requirements of Power Converters
CO2	Configure Interrupts of the DSP TMS320LF2407A and Event manager to implement Pulse Width Modulation
CO3	Develop Assembly Language Programs using DSP TMS320LF2407A for the real time control of Power Electronic Converters
CO4	Develop software for the TMS320F2812 DSP using the C-programming language

List of Experiments on TMS320LF2407A Processor (using Assembly Language)

1. General Programs to get familiarity with addressing modes, instruction set, arithmetic and logical operations such as:
   a. Arithmetic and logical operations
   b. Direct & Indirect Data Transfer
   c. Sorting of Data in Ascending order and Descending order
   d. Square root of positive integer
   e. Maximum and minimum of given set of numbers
2. Study of the phenomenon of Aliasing
3. Study of the on-chip ADC of TMS320LF2407 processor.
4. Study of the GPIO functionality.
5. Waveform generation with on board DAC of EVM TMS320LF2407
6. PWM signal generation using event manager with dead time
7. Study of the interrupts of TMS320LF2407 processor.
8. Space Vector Modulation of a 3-Phase VSI

List of Experiments on TMS320F2812 Processor (using C-Programming Language)

9. General Programs to get familiarity with syntax, arithmetic and logical operations (the list is similar to expt.1)
10. Solution of Difference equation
11. Study of interrupts & GPIO
12. Generation of Basic PWM signals
13. Study of Quadrature Encoder Pulse (QEP) Unit
14. Implementation of sine-triangle PWM scheme
15. Implementation of Sine-triangle PWM with Launch XL-F28069M
16. Implementation of SVPWM with Launch XL-F28377S
17. Control of BLDC motor with DRV8301

MH 5013	Optimization Techniques	3 – 0 – 0	3 Credits

Course Outcomes:

CO1	Recognize the importance of optimization techniques in solving practical problems in industry
CO2	Understand Optimization models and apply them to real life problems
CO3	Design new models to improve decision making, critical thinking and analysis of decision problems

Linear Programming : Introduction and formulation of models, Simple applications in Circuit Designs, Convexity, Simplex method, Big-M method, Two-phase method, degeneracy, non-existent and unbounded solutions, Duality in LPP, Dual simplex method, Sensitivity analysis, Transportation and Assignment problems, Traveling salesman problem using branch & bound algorithm.

Nonlinear Programming : Classical optimization methods, equality and inequality constraints, Lagrange multipliers and Kuhn-Tucker conditions, Quadratic forms, Quadratic programming problem and Wolfes' method.

Search Methods : One dimensional optimization, Sequential search, Fibonacci search, Multidimensional search methods, Uni-variate search, Gradient methods_Steepest descent/ascent methods, Conjugate gradient method, Fletcher-Reeves method, Penalty function approaches.

Dynamic Programming : Principle of optimality, Recursive relations, Solution of LPP, Simple examples.

Integer Linear Programming : Gomory's cutting plane method, Branch and Bound algorithm, Knapsack problem.

Geometric Programming: Polynomials, AM-GM inequality, Unconstrained GP, Constrained GP, Simple Applications

Text Books :

1. J.C. Pant : Introduction to Optimization, Jain Brothers, New Delhi, 2014
2. S.S. Rao :Optimization Theory and applications, New Age, New Delhi, 2012

Reference Book:

1. A Ravindran, KM Ragsdell& GV Reklaitis, Engineering Optimization, Wiley India,2006

EE5111	Modern Control Theory	3 – 0 – 0	3 Credits

Course Outcomes:

CO1	Develop mathematical models of physical systems.
CO2	Design optimal controllers for physical systems including power electronic and power systems.
CO3	Analyze the issues related to the stability of automatic control systems.
CO4	Design complex nonlinear systems by linearizing them

System representation: Introduction to state and state variables - system representation in state variable form - transformations - Phase variable form - Canonical forms – Physical systems - Plant models – Representation using state function - Lagrange linearization

Time response:
State transition matrix – Properties and methods of valuation - Time response of linear systems -State diagrams - Resolvant matrix - Resolvant algorithm

Controllability and observability:
Definition and concepts - Criteria for controllability and observability - State variable feedback - Pole placement - Luenberg observer design

Stability:
Introduction - definition of stability - stability in the sense of Lyapunov - stability of linear systems - transient response - Behavior of estimation - stability of non linear systems - generation of Lyapunov functions

Optimal control:
Formulation of the optimal control problem - method of calculus of variations - use of Hamiltonian method - Pontryagin's minimum principle - Optimal control problem - Hamilton – Jacobi approach - Continuous time linear state regulator matrix riccati equation - Methods of solution – State variable feedback design.

Text Books:

1. Katsuhiko Ogata: Modern control Engineering, Prentice-Hall of India, 2010
2. M. Gopal: Modern Control Systems Theory, Wiley Eastern Limited, New Delhi, 2005

Reference Books:

1. Schultz &Melsa: State functions & linear control systems McGraw Hill Book Co.. New York, 1998.
2. Chidambara&Ganapathy: An Introduction to control of dynamic systems, Sehgal Educational consultants and publishers Pvt. Ltd. Faridabad

EE 5112	Control & Integration of Renewable Energy Sources	3 – 0 – 0	3 Credits

Course Outcomes:

CO1	Knowledge on different renewable energy sources and storage devices
CO2	Recognize, model and simulate different renewable energy sources
CO3	Analyze, model and simulate basic control strategies required for grid connection
CO4	Implement a complete system for standalone/grid connected system

Introduction: Electric grid introduction, Supply guarantee and power quality, Stability, Effects of renewable energy penetration into the grid, Boundaries of the actual grid configuration, Consumption models and patterns, static and dynamic energy conversion technologies, interfacing requirements

Dynamic Energy Conversion Technologies: Introduction to different conventional and nonconventional dynamic generation technologies, principle of operation and analysis of reciprocating engines, gas and micro turbines, hydro and wind based generation technologies, control and integrated operation of different dynamic energy conversion devices

Static Energy Conversion Technologies: Introduction to different conventional and nonconventional static generation technologies, principle of operation and analysis of fuel cell, photovoltaic based generators, and wind based generation technologies, different storage technologies such as batteries, fly wheels and ultra capacitors, plug-in-hybrid vehicles, control and integrated operation of different static energy conversion devices

Real and reactive power control: Control issues and challenges in Diesel, PV, wind and fuel cell based generators, PLL, Modulation Techniques, Dimensioning of filters, Linear and nonlinear controllers, predictive controllers and adaptive controllers, Fault-ride through Capabilities, Load frequency and Voltage Control

Integration of different Energy Conversion Technologies: Resources evaluation and needs, Dimensioning integration systems, Optimized integrated systems, Interfacing requirements, integrated Control of different resources, Distributed versus Centralized Control, Synchro Converters, Grid connected and Islanding Operations, stability and protection issues, load sharing, Cases studies

Text books:

1. Ali Keyhani Mohammad Marwali and Min Dai, “Integration and Control of Renewable Energy in Electric Power System” John Wiley publishing company
2. S. Chowdhury, S. P. Chowdhury, P. Crossley, “Microgrids and Active Distribution Networks”, IET Power Electronics Series, 2012
3. G. Masters, “Renewable and Efficient Electric Power Systems”, IEEE-Wiley Publishers, 2013

References:

1. Quing-Chang Zhong, “Control of Power Inverters in Renewable Energy and Smart Grid Integration”, Wiley, IEEE Press
2. Bin Wu, Yongqiang Lang, NavidZargari, “Power Conversion and Control of Wind Energy Systems”, Wiley 2011.

EE5113	Electromagnetic Interference & Compatibility	3 – 0 – 0	3 Credits

Course Outcomes:

CO1	Recognize the sources of Conducted and radiated EMI in Power ElectronicConverters and consumer appliances and suggest remedial measures tomitigate the problems
CO2	Assess the insertion loss and design EMI filters to reduce the loss
CO3	Design EMI filters, common-mode chokesand RC-snubber circuits measuresto keep the interference within tolerable limits

Introduction: Sources of conducted and radiated EMI, EMC standardization and description, measuring instruments, conducted EMI references, EMI in power electronic equipment: EMI from power semiconductors circuits.

Noise suppression in relay systems: AC switching relays, shielded transformers, capacitor filters, EMI generation and reduction at source, influence of layout and control of parasites.

EMI filter elements: Capacitors, choke coils, resistors, EMI filter circuits. Ferrite breeds, feed through filters, bifilar wound choke filter, EMI filters at source, EMI filter at output

EMI filter design for insertion loss: Worst case insertion loss, design method for mismatched impedance condition and EMI filters with common mode choke-coils, IEC standards on EMI

EMI in Switch Mode Power Supplies: EMI propagation modes, power line conducted-mode inference, safety regulations (ground return currents), Power line filters, suppressing EMI at sources, Line impedance stabilization network (LISN), line filter design, common-mode line filter inductors- design& example, series –mode inductors and problems, EMI measurements.

Faraday Screens for EMI prevention: As applied to switching devices, transformers faraday screen and safety screens, faradayscreens on output components, reducing radiated EMI on gapped transformer cores, metal screens, electrostatic screens in transformers

Text Books:

1. Laszlo Tihanyi: Electromagnetic Compatibility in Power Electronics, IEEE Press.
2. R. F. Ficchi: Practical Design for Electromagnetic Compatibility, Hayden Book Co.

Reference:

1. Keith H Billings, Handbook on Switch-Mode power supplies, McGraw-Hill Publisher, 1989.

EE 5114	Nonlinear Control Systems	3– 0 – 0	3 Credits

Course Outcomes:

CO1	Understand the behavioral properties of nonlinear controlled systems
CO2	Analyze stability analysis of nonlinear systems, feedback linearization control method, Lyapunov design and sliding mode control method.
CO3	Emphasizes modeling uncertainty characterization, and formulate & solve basic robust and nonlinear controller design problems.
CO4	The course will provide an introductory treatment of advanced analysis and synthesis methods for nonlinear systems, emphasizing also the use of computer-aided design tools (Criterion 3(k)).

Introduction and classical techniques: Characteristics of nonlinear systems - classification of equilibrium points - limit cycles - analysis of systems with piecewise constant inputs using phase plane analysis - perturbation techniques- periodic orbits - stability of periodic solutions - singular perurbation model - slow and fast manifolds.

LyapunovStabilty and Design: Stability of Nonlinear Systems - Lyapunov stability - local stability - local linearization and stability in the small - Direct method of Lyapunov - generation of Lyapunov function for linear and nonlinear systems - variable gradient method - Centre manifold theorem - region of attraction - Invariance theorems – Input output stability - L stability - L stability of state models - L2 stability- Lyapunov based design – Lyapunonv redesign - Robust stabilization - Nonlinear Damping - backstepping - sliding mode control – adaptive control - Model controller - model reference adaptive control

Harmonic Linearization and Describing Function Method: Harmonic linearization - filter hypothesis - describing function of standard nonlinearities- study of limit cycles (amplitude and frequency) using SIDF- Dual Input Describing function - study of sub-harmonic oscillations - correction on describing functions

Feedback Control and Feedback Stabilization: Analysis of feedback systems - Circle Criterion - Popov Criterion - simultaneous Lyapunov functions - Feedback linearization - stabilization - regulation via integral control - gain scheduling - input stat linearization - input output linearization - state feedback control - stabilization - tracking - integral control.

Text Books:

1. Hassan K. Khalil, Nonlinear Systems, Prentice - Hall International (UK), 1996.
2. Slotine& W.LI, Applied Nonlinear Control, Prentice Hall, Engloe Wood, New Jersey, 1991

References:

1. A Isidori, Nonlinear Control systems, Springer verlag, New York, 1995.
2. S. Wiggins, Introduction to Applied Nonlinear Dynamical Systems and chaos, Springer Verlag, New York, 1990.
3. H. Nijmeijer& A.J. Van der Schaft, Nonlinear Dynamic control Systems, Springer Verlag, Berlin, 1990.
4. Arther E Gelb & Vender Velde, Multiple input Describing function and Nonlinear System Design, McGraw Hill, 1968.

EE 5211	AI Techniques in Power Engineering	3 – 0 – 0	3 Credits

Course Outcomes:

CO1	Differentiate between Algorithmic based methods and knowledge based methods
CO2	Use the soft computing techniques for power system problems
CO3	Use appropriate AI framework for solving power system problems
CO4	Apply GA to power system optimization problems

INTRODUCTION: Artificial Neural Networks (ANN) – definition and fundamental concepts – Biological neural networks – Artificial neuron – activation functions – setting of weights – typical architectures – biases and thresholds – learning/training laws and algorithms. Perceptron – architectures, ADALINE and MADLINE – linear separability- XOR function.

ANN PARADIGMS: ADALINE – feed forward networks – Back Propagation algorithm- number of hidden layers – gradient decent algorithm – Radial Basis Function (RBF) network. Kohonen's self organizing map (SOM), Learning Vector Quantization (LVQ) and its types – Functional Link Networks (FLN) – Bidirectional Associative Memory (BAM) – Hopfield Neural Network.

CLASSICAL AND FUZZY SETS: Introduction to classical sets- properties, Operations and relations; Fuzzy sets, Membership, Operations, Properties, Fuzzy relations, Cardinalities, Membership functions.

FUZZY LOGIC CONTROLLER (FLC): Fuzzy logic system components: Fuzzification, Inference engine (development of rule base and decision making system), Defuzzification to crisp sets- Defuzzification methods.

APPLICATIONS OF ANN AND FLC: Applications of ANN- Load flow, Economic load dispatch, Load forecasting, PWM controllers, selected harmonic elimination- PWM space vector- PWM vector controlled drive- Speed estimation and flux estimation of induction motor. Applications of FLC**-** Load frequency control- Single area and two area systems- Speed control of DC motor.

Text Books

1. Neural Networks, Fuzzy logic, Genetic algorithms: synthesis and applications by Rajasekharan and pai – PHI Publication.
2. Fuzzy logic with Fuzzy Applications – T.J Ross – Mc Graw Hill Inc, 1997.

References

1. Neural Networks: A comprehensive Foundation – Simon Haykins, Pearson Edition, 2003.
2. Yegnanarayana B, "Artificial Neural Networks", Prentice hall of India Private Ltd., New Delhi, 1999.
3. Zurada, J.M., 'Introduction to Artificial Neural Systems', Jaico publishing house, Bombay, 1992.
4. Zimmermann, H.J., 'Fuzzy set theory and its applications', Allied publishers limited, Madras, 2001

EE 5214	Smart Grid Technologies		3– 0 –0	3 Credits

Course Outcomes:

CO1	Understand features of Smart Grid in the context of Indian Grid.
CO2	Assess the role of automation in Transmission/Distribution
CO3	Apply Evolutionary Algorithms for the Smart Grid/Distribution Generation.
CO4	Understand operation and importance of PMUs, PDCs, WAMS, Voltage and Frequency control in Micro Grids.

Introduction to Smart Grid: Introduction to Smart Grid - Working definitions of Smart Grid and Associated Concepts – Smart Grid Functions – Traditional Power Grid and Smart Grid – New Technologies for Smart Grid – Advantages – Indian Smart Grid – Key Challenges for Smart Grid.

Smart Grid Architecture: Components and Architecture of Smart Grid Design – Review of the proposed architectures for Smart Grid. The fundamental components of Smart Grid designs – Transmission Automation – Distribution Automation – Renewable Integration

Tools and Techniques for Smart Grid: Computational Techniques – Static and Dynamic Optimization Techniques – Computational Intelligence Techniques – Evolutionary Algorithms – Artificial Intelligence techniques.

Distribution Generation Technologies: Introduction to Renewable Energy Technologies – Micro grids – Storage Technologies –Electric Vehicles and plug – in hybrids – Environmental impact and Climate Change – Economic Issues.

Communication Technologies and Smart Grid: Introduction to Communication Technology – Synchro-Phasor Measurement Units (PMUs) – Wide Area Measurement Systems (WAMS).

Control of Smart Power Grid System: Load Frequency Control (LFC) in Micro Grid System – Voltage Control in Micro Grid System – Reactive Power Control in Smart Grid. Case Studies and Test beds for the Smart Grids.

Text Books:

1. Stuart Borlase, Smart Grids, Infrastructure, Technology and Solutions, CRC Press, 2013
2. Gil Masters, Renewable and Efficient Electric Power System, Wiley–IEEE Press, 2004.

Reference Books:

1. A.G. Phadke and J.S. Thorp, "Synchronized Phasor Measurements and their Applications", Springer Edition, 2010.
2. T. Ackermann, Wind Power in Power Systems, Hoboken, NJ, USA, John Wiley, 2005

EE5141	**Seminar-1**		**0– 0 – 2**	**1 Credit**

Pre-requisites: None

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

CO1	Understand advanced topics in power electronics & drives
CO2	Improve language and communication skills

EE 5151	Advanced Power Electronics	4 – 0 – 0	4 Credits

Pre-requisites: Analysis of Power Converters

Course Outcomes:

CO1	Modeling of power converters under steady state and small signal condition.
CO2	Develop power converters with better performance for challenging applications
CO3	Analyze and design power converters & feedback loops, selection of power circuit components
CO4	Analyze power quality problems and suggest solutions

Resonant Converters: Introduction - Basic resonant circuit concepts - Classification - Load resonant converters - Resonant switch converters - Zero voltage switching clamped voltage converters - Resonant DC link inverters High frequency link integral half cycle converters - Phase modulated resonant converters.

Modeling of DC-DC Converters: Basic ac modeling approach - State space averaging - Circuit averaging and averaged switch modeling - Canonical circuit modeling - Converter transfer functions for buck - boost and buck-boost topologies.

Current Mode Control: Introduction - types - advantages and disadvantages - Slope compensation - Determination of duty cycle and transfer functions for buck - boost and buck-boost converters.

Design of Switching Power Converters: Controller Design: Introduction - mechanism of loop stabilization - Shaping E/A gains vs frequency characteristics - Conditional stability in feed-back loop - Stabilizing a continuous mode forward and fly-back converter - Feed-back loop stabilization with current mode control - right plane zero.

Design of Power Converters Components: Design of magnetic components-design of transformer - Design of Inductor and current transformer - Selection of filter capacitors - Selection of ratings for devices - input filter design - Thermal design

Text books:

1. Power Electronics-circuits, Devices & Applications: M.H.Rashid, PHI.
2. Power Electronics: Converters, Applications & Design: N Mohan, T.M.Undeland, W. P.Robbins, J.Wiley& Sons.

References:

1. Switching Power Supply Design: Abraham I. Pressman, McGraw Hill International.
2. M. D Singh, K B. Kanchandani, Power Electronics, Tata McGraw Hill International
3. IEEE Publications on Power Electronics

EE5152	Advanced Electric Drives	3 – 1 – 0	4 Credits

Pre-requisites: Analysis of Power Converters

Course Outcomes:

CO1	Design controllers for closed-loop operation of separately excited DC motor drives
CO2	Develop high performance induction motor drives using the principles of Scalar control, Vector control and Direct Torque Control
CO3	Formulate control strategies for VSI fed sensor-less induction motor drives, CSI fed induction motor drives, and VSI fed poly-phase induction motors
CO4	Implement control schemes for PMSM, BLDC and Switched Reluctance Motor drives

Separately Excited DC-motor Drives: Introduction, Review of DC-motor drives, Speed control of a Separately excited DC motor drive with controlled rectifiers and choppers, Review of controllers, need for anti-windup feature for integral controllers, Speed control of a separately excited DC drive with inner current loop and outer speed loop, Design of current loop with pole-zero cancellation, Design of speed loop with symmetrical optimization technique

Induction Motor drives: Implementation of V/f control with slip compensation scheme, Review of dq0 model of 3-Ph IM with simulation studies, Principle of vector control of IM, Direct vector control, Indirect vector control with feedback, Indirect vector control with feed-forward, Indirect vector control in various frames of reference, Decoupling of vector control with feed forward compensation, sensor-less control of IM, Direct Torque Control of IM, Speed control of wound induction motor with rotor side control, introduction to five-phase induction motor drives

Permanent Magnet Drives: PM Synchronous motors: Types, Construction, operating principle, Expression for torque, Model of PMSM, Implementation of vector control for PMSM, BLDC drives

Switched Reluctance Motor Drives: Switched Reluctance Motor: Construction, Operating Principle, Torque expression, converters for SRM drives, Control of SRM drives

Text Books:

1. Modern Power Electronics & AC Drives – B.K. Bose, Pearson, First edition
2. Electric Motor Drives: Modeling, Analysis and Control – R. Krishnan – Prentice Hall

Reference Books:

1. Vector Control of Electric Drives: Peter Vas, Oxford Publishers
2. High-power Converters and AC Drives: Bin-Wu, IEEE Press, John Wiley & Sons
3. Simulation of Power Electronic Circuits: M. B. Patil, V. Ramanarayanan, V.T. Ranganathan, Narosa Publications, 2013
4. Relevant Papers from journals

EE5153	**Digital Control Systems**	**4 – 0 – 0**	**4 Credits**

Pre-requisites:

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

CO1	Evaluate the output of a digital system for a given input.
CO2	Describe the dynamics of a Linear, Time Invariant and Causal digital systems through difference equations
CO3	Analyze digital systems using the Z-transformation
CO4	Design digital controllers for Power Electronic Systems

Introduction: Digital control systems - Quantizing and quantization error - Data acquisition - Conversion and distribution system

Z-Transform:Z-transform - Z-transforms of elementary functions - Important properties and theorems - Inverse z-transform - Z-transform method of solving difference equations

Z-Plane Analysis Of Discrete-Time Control Systems: Impulse sampling and data hold - Pulse transfer function - Realization of digital controllers and digital filters - Mapping between s-plane and z-plane - Stability analysis of closed loop systems in z-plane - Transient and steady state analyses

State Space Analysis: State space representation of digital control systems - Solution of discrete time state space equations - Pulse transfer function matrix – Discritisation of continuous time state space equations - Lyapunov stability analysis

Pole Placement & Observer Design: Controllability - Observability

Quadratic Optimal Control Systems: Design via pole placement - State observers. - Quadratic optimal control - Steady state quadratic optimal control - Quadratic optimal control of a servo system

Text Books:

1. M. Gopal: *Digital control engineering*, New Age Int. Ltd., India, 1998.
2. K. Ogata:*Discrete time control systems*, Pearson Education, 2006.
3. K. Ogata, "Modern control engineering"- PHI, 1991.
4. B. C. Kuo, "Digital control systems"- Holt Saunder's International Edition, 1991.

EE 5154	Electric Drives Lab	0 – 0 – 3	2 Credits

Course Outcomes:

CO1	Student get practical training and hands-on for the hardware and software applications used in electric drive.
CO2	Understand the practical problems and limitations of the methods used in electric drives

1) Torque-Speed characteristics of DC motor using DC chopper.
2) Symmetrical angle control of 1-phase AC motor connected to AC voltage controller
3) Single-Phase dual converter connected separately excited DC motor drive
4) Speed control of 3-phase induction motor using open-loop V/f control technique
5) Torque-Speed characteristics of a 3-phase induction motor using IM-IM comprehensive drive system
6) Study of a Neutral Point Clamped inverter fed three-phase induction motor drive
7) Pulse width modulation control of 1-phase AC motor connected to AC voltage controller
8) Torque-Speed characteristics of a 3-phase Permanent Magnet Synchronous Motor (PMSM) using PMSM-IM comprehensive drive system
9) Torque-speed characteristics of a Separately Excited DC motor Drive fed by a two-pulse centre-tapped thyristor rectifier.
10) Torque-speed characteristics of a 6-pulse fully controlled rectifier fed Separately Excited DC motor Drive
11) Study of a four-quadrant Separately excited DC motor drive fed by dual-converter with circulating current control
12) Study Class-D commutated chopper fed Separately Excited DC motor Drive
13) Verification of spectral performance of a 3-Ph VSI with V/Hz control of 3-Ph IM drives
14) Torque speed characteristics of a 3-Ph induction motor fed by a 3-Ph VSI
15) Implementation of centre spaced space vector modulation with DSP for V/Hz control of induction motor drives
16) Implementation of discontinuous space vector modulation with DSP for V/Hz control of induction motor drives

EE 5155	**Power Electronic Simulation Lab**	**3 – 0 – 0**	**3 Credits**

Pre-requisites: Analysis of Power Converters, Advanced Power Electronics& Advanced Electric Drives

Course Outcomes:

CO1	Use simulators as a learning aid and gain a profound insight into the working of various power electronic converters and drive systems.
CO2	Validate the performance of various multilevel inverter with different PWM schemes.
CO3	Explore the behavior of new circuits of power converters.
CO4	Use simulators as an aiding tool to design power electronic and drive systems

1. Closed loop implementation of buck and boost dc-dc converters.
   (a) Design of various elements such as inductor, capacitor for continuous current operation.
   (b) State-space modelling.
   (c) Dynamic response with change in load.

2. Sine-PWM techniques for single-phase half-bridge and full-bridge inverters.
   (a) Implementation unipolar and bipolar PWM techniques.
   (b) Observation of line-voltage with change in amplitude modulation index.
   (c) Observation of harmonic spectrum of line-voltage with change in frequency modulation index.

3. Sine-PWM techniques for three-phase two-level inverters.
   (a) Observation of line-voltage with change in amplitude modulation index.
   (b) Observation of harmonic spectrum of line-voltage with change in frequency modulation index.
   (c) Over-modulation and zero-sequence harmonic injection.

4. Closed loop implementation single-phase high power factor rectifiers (Boost rectifier and PWM rectifier).
   (a) Observation of source current THD and its reduction to IEEE recommended value.
   (b) Observation of power factor and input displacement factor.
   (c) Regulation of load voltage with change in load current and dc voltage reference.

5. Closed loop implementation three-phase high power factor rectifiers (Current controlled mode and voltage control mode).
   (a) Observation of source current THD and its reduction to IEEE recommended value.
   (b) Observation of power factor and input displacement factor.
   (c) Regulation of load voltage with change in load current and dc voltage reference.

6. Space vector modulation (SVM) for three-phase two-level inverters.
   (a) Implementation of SVM with classical method.
   (b) Implementation of SVM with Kim-Sul method.
   (c) Observation of line and phase voltages with change in amplitude modulation index.
   (d) Observation of harmonic spectra of line and phase voltages with change in frequency modulation index.
   (e) Observation of improvements over Sine-PWM technique

7. Sine PWM techniques for three-phase five-level diode clamped multilevel inverter.
   (a) Implementation of level-shifted PWM technique.
   (b) Observation of line and phase voltages with change in amplitude modulation index.
   (c) Observation of harmonic spectra of line and phase voltages with change in frequency modulation index.
   (d) Over-modulation and zero-sequence harmonic injection.

8. Sine PWM techniques for three-phase five-level flying capacitor multilevel inverter and three-phase five-level cascade H-bride (CHB) inverters.
   (a) Implementation of level-shifted and phase-shifted PWM technique.
   (b) Observation of line and phase voltages with change in amplitude modulation index.
   (c) Observation of harmonic spectra of line and phase voltages with change in frequency modulation index.
   (d) Over-modulation and zero-sequence harmonic injection.

9. Space vector modulation for three-phase three-level multilevel inverters.
   (a) Implementation of SVM for three-level diode-clamped multilevel inverter.
   (b) Implementation of SVM for five-level CHB multilevel inverter.
   (c) Observation of harmonic spectra of line and phase.
   (d) Observation of improvements over Sine-PWM technique.

10. Field-oriented control of three-phase induction motor.
   (a) Implementation of FOC for a given induction motor.
   (b) Observation of its dynamic performance with change in load conditions.

11. Direct torque control of three-phase induction motor.
   (a) Implementation of DTC for a given induction motor.
   (b) Observation of its dynamic performance with change in load conditions.

12. Simulation of DC-DC converters with WEBENCH

EE 5161	Applications of Power Converters	3 – 0 – 0	3 Credits

Pre-requisites: Analysis of Power Converters

Course Outcomes:

CO1	Analyze power electronic application requirements.
CO2	Identify suitable power converter from the available configurations.
CO3	Develop improved power converters for any stringent application requirements.
CO4	Improvise the existing control techniques to suit the application. Design of Bi-directional converters for charge/discharge applications

Inverters for Induction Heating: For induction cooking, induction hardening, melting, and welding applications.

Power Converters for Lighting, pumping and refrigeration Systems: Electronic ballast, LED power drivers for indoor and outdoor applications. PFC based grid fed LED drivers, PV / battery fed LED drivers. PV fed power supplies for pumping/refrigeration Applications.

High Voltage Power Supplies - power supplies for X-ray applications - power supplies for radar applications - power supplies for space applications.

Low voltage high current power supplies: power converters for modern microprocessor and computer loads

Bi-directional DC-DC (BDC) converters: electric traction, automotive Electronics and charge/discharge applications, Line Conditioners and Solar Charge Controllers

Text books:

1. Ali Emadi, A. Nasiri, and S. B. Bekiarov: Uninterruptible Power Supplies and Active Filters, CRC Press, 2005.
2. M. Ehsani, Y. Gao, E. G. Sebastien and A. Emadi: Modern Electric, Hybrid Electric and Fuel Cell Vehicles, 1st Edition,CRC Press, 2004.

References:

1. William Ribbens: Understanding Automotive Electronics, Newnes, 2003.
2. Current literature

EE5162	**Modeling and Simulation of Power Electronic Systems**	**3 – 0 – 0**	**3 Credits**

Pre-requisites: Analysis of Power Converters

Course Outcomes:

CO1	Understand the back ground activities i.e. numerical solution used in the simulation software.
CO2	Can judge or properly choose the required numerical solver to be used for analysis.
CO3	Can understand and debug the convergence problems occurring during simulation.

Detailed syllabus

Introduction: Challenges in computer simulation - Simulation process - mechanics of simulation, Solution techniques for time domain analysis - Equation solvers, circuit-oriented simulators.

Simulation of power electronic converters: MNA and ST Approaches- Nodal Analysis, Modified Nodal Analysis, The Spare Tableau Approach, Nonlinear Circuits - The Newton-Raphson Method, Computation Time, Convergence Issues, Nonlinear Circuit Equations, Introduction to Transient Simulation - Introduction, Discretization of Time, Transient Analysis, Accuracy and Stability, Explicit and Implicit Schemes, Methods for Transient Simulation - FE, BE and TRZ, Transient Analysis in Circuit Simulation, Equivalent Circuit Approach: RC Circuit, Buck Converter; Some Practical Aspects: Undamped Oscillations, Ringing, Global Error in Switching Circuits, Round-off Error, Assessment of Accuracy, Singular Matrix Problem, Trapezoidal integration, M & N method for simulating power electronic converters (with buck converter as a representative example).

Switching function: Introduction, Application of the switching function technique, Properties of the switching function, Voltage-Current relations in switched circuits - Single Switch, Parallel Switch, Pulse Width Modulation- Unipolar, PWM Signal of a composite function, bipolar square wave modulation, Mathematical Modeling of Buck Converter, Modeling using switching function-buck converter, Rectifier, 3-phase VSI inverter, matrix converter, m-phase rectifier. PWM rectifier topologies, Modeling of power electronic converters - PWM rectifier in different frames-abc, alpha-beta and d-q.

Modeling, simulation of switching converters with state space averaging, hybrid model: State space approach, averaging method, State Space Averaging Technique – Modeling AND linearization of converter transfer functions- Hybrid Modeling for DC-DC converter.

Text book:

1. M. B. Patil, V. Ramnarayanan, V. T. Ranganathan**:** *Simulation of Power Electronic Converters***,** 1st ed., Narosa Publishers, 2010

Reference book:

1. Ned Mohan, Undeland and Robbins**, "**Power Electronics: Converters, Design and control**"-** 2nd ed., John Wiley.

EE 5163	**Power Quality Improvement Techniques**	**3 – 0 – 0**	**3 Credits**

Course Outcomes:

CO1	Assess the severity of power quality problems in distribution system;
CO2	Analyze current and voltage related power quality issues
CO3	Develop control techniques for compensating devices

Introduction to the Power Quality Issues: Definition and significance of Power quality - Power quality terms: Transients, Long-duration voltage variations, Short-duration voltage variations, Voltage imbalance, Waveform distortion, Voltage fluctuation, CBEMA and ITI curves

Waveform Distortion: Introduction, Voltage versus current distortion, Harmonics versus transients, Harmonics indices: Total Harmonics Distortion (THD) and Total Demand distortion (TDD); Harmonic standards; Harmonic analysis; Harmonic phase sequence; Triplen harmonics; Interharmonics

Harmonic Sources: Introduction; Harmonics generated from electrical machines such as transformers and rotating machines; Arcing devices; Static power conversion: Phase controlled and uncontrolled rectifiers, AC voltage regulators, Cycloconverters, Pulse width modulated inverters; Converter fed ac and dc drives;

Effects of Harmonic Distortion: Resonances; Effects of harmonics on rotating machines; Effect of harmonics on static power plant; Power assessment with distorted waveforms; Effect of harmonics on measuring instruments; Harmonic interference with ripple control systems; Harmonic interference with power system protection; Effect of harmonics on consumer equipment; Interference with communication systems

Harmonic Elimination: Passive power filters: Design, Advantages and disadvantageous; Shunt active power filters: Operating principle, Configurations, State of the art, Design and control strategies. Three-phase four-wire shunt active power filters

Voltage Quality: Sources of Sags, Swell, Unbalance and Harmonics; Voltage quality standards; Effects of sags, Swell, Unbalance and harmonics; Voltage sag magnitude due to fault; Voltage sag magnitude calculation based on influence of cross section of conductor, transformer and fault levels; Critical distance for a voltage sag magnitude; Causes of phase-angle jumps in voltage; Classification of voltage sags, voltage sag transformation due to transformers

Methods for improving Voltage Quality: Series active power filters: Operating principle, Configurations, State of the art, Design and control strategies. Three-phase four-wire series active power filters

Unified Power Quality Conditioner (UPQC): Introduction; design and control; Three-phase three-wire UPQC and three-phase four-wire UPQC topologies, Multilevel inverters based UPQC topologies, Application of multilevel inverters in large rating active power filters

Text books:

1. Electrical Power Systems Quality, Dugan Roger C, Santoso Surya, McGranaghan , Marks F. Beaty and H. Wayre, 3rd edition, McGraw Hill, 2012.
2. Power System Harmonics, J. Arrillaga, N.R. Watson, John Wiley & Sons Ltd, Second Edition, 2003.
3. Instantaneous Power Theory and Applications to Power Conditioning, Hirofumi Akagi, Edson Hirokazu Watanabe, Mauricio Aredes, Wiley-IEEE Press, 2007.
4. Understanding power quality problems, Math H. Bollen, IEEE Press.

References:

1. Power Quality Enhancement Using Custom Power Devices, Ghosh Arindam, LedwichGerard, Springer, 2009.
2. Power Quality: Problems and Mitigation Techniques, Bhim Singh, Ambrish Chandra, Kamal Al-Haddad, Wiley, 2014.
3. IEEE Transactions and Standards.

EE 5164	Electric Vehicles	3 – 0 – 0	3 Credits

Course Outcomes:

CO1	Understand the basic concepts of electric vehicles and popular traction systems.
CO2	Analyze the characteristics of train movement other traction mechanics.
CO3	Understand the drive-train topologies and advanced propulsion techniques.
CO4	Analyze the various energy storage methodologies and systems of train lighting

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

Methods of traction - track electrification - DC system - single phase and three-phase low frequency and high frequency system - composite system - kando system - comparison between AC and DC systems - problems of single phase traction with current unbalance and voltage balance.

Traction mechanics: Mechanics of traction movement - speed-time curves for different services - trapezoidal and quadrilateral speed-time curves - tractive effort requirements and problems - power - specific energy consumption - effect of varying acceleration and braking - Retardation - adhesive weight and braking retardation - coefficient of adhesion.

Electric drive-trains: Basic concept of electric traction - introduction to various electric drive-train topologies - power flow control in electric drive-train topologies - fuel efficiency analysis

Train lighting: Special requirements of train lighting - methods of obtaining unidirectional polarity constant output-single battery system - Double battery parallel block system - coach wiring - Lighting by making use of 25 KV AC supply.

Electric propulsion unit: Introduction to electric components used in electric vehicles - Configuration and control of DC Motor drives - Configuration and control of Induction Motor drives - Configuration and control of Permanent Magnet Motor drives - Configuration and control of Switch Reluctance Motor drives - Drive system efficiency, Concept of Hybrid Electric Vehicles

Energy storage: Introduction to Energy Storage Requirements in Electric Vehicles - Battery based energy storage and its analysis - Fuel Cell based energy storage and its analysis - Super Capacitor based energy storage and its analysis - Flywheel based energy storage and its analysis - Hybridization of different energy storage devices

Text books:

1. Ali Emadi, Advanced Electric Drive Vehicles, CRC Press, 2014.
2. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.

References:

1. MehrdadEhsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.
2. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.
3. H. Partab: Modern Electric Traction - DhanpatRai& Co, 2007.
4. S. Rao: EHV AC and HVDC Transmission Engineering and Practice, 3rd edition, Khanna Pub, 1997.

EE 5165	Energy Auditing and Management		3 – 0 – 0	3 Credits

Course Outcomes:

CO1	Understand the need and importance of energy audit and management
C02	Identify the equipment and areas of a system where energy conservation and audit is necessary
CO3	Identify the type and need for instruments used in energy audit
CO4	Design and analyse a process of conducting an energy audit
C04	Evaluate the benefits of different energy management techniques

Energy audit and demand side management (DSM) in power utilities: Energy Scenario & Conservation -Demand Forecasting Techniques- Integrated Optimal Strategy for Reduction of T&D Losses - DSM Techniques and Methodologies- Loss Reduction in Primary and Secondary Distribution system and capacitors - Energy Management – Role of Energy Managers - Energy Audit - Metering

Energy audit: Energy audit concepts, Basic elements and measurements, Mass and energy balances, Scope of energy auditing in industries, Evaluation of energy conserving opportunities and environmental management, Preparation and presentation of energy audit reports, case studies and potential energy savings.

Instrumentation: Evaluation and instrumentation techniques for renewable energy systems (solar thermal, photovoltaic and wind energy); energy management devices; micro controller based systems.

Energy conservation: Energy conservation in HVAC systems and thermal power plants, Solar systems, Fan and Lighting Systems - Different light sources and luminous efficacy, Energy conservation in electrical devices and systems, Economic evaluation of energy conservation measures, Electric motors and transformers, Inverters and UPS, Voltages stabilizers.

Text books:

1. Larry C. Witte, Schmidt & Brown, Industrial energy management and utilization. Hemisphere publishing, Co. New York, 1988.
2. Wayne. C Turner :Energy management handbook, Wiley Inter-science publications. New York, 1982.

References:

1. D. A. Reay, Industrial Energy Conservation - Pergamon Press, 1980. T.L. Boten,
2. Liptak B.G., (Ed) Instrument Engineers Handbook, Chinton Book Company, 2004.
3. Hodge B.K, Analysis and Design of Energy Systems, Prentice Hall, 2002.

EE 5166	DSP Controlled Drives	3 – 0 – 0	3 Credits

Pre-requisites: Applications of Digital Signal Processors

Course Outcomes:

CO1	Interface the DSP platform with sensors such as hall-effect voltage sensors, hall-effect current sensors, shaft encoder for data acquisition for motor drive applications
CO2	Scale and normalize the data to suit the requirements of the drive system
CO3	Exploit the architectural features of the DSP platform to design and implement algorithms for the realization of controllers, Pulse Width Modulators and observers

Overview of TMS320LF2407 DSP controller: Review ofInstruction Set, Interrupts, normalization and number formatting.

Clarke's and Park's transformations: Review ofClarke's and Park's transformations, Implementation of Clarke's and Park's transformation using TMS320LF2407 DSP

Implementation of PWM Techniques for 3-Ph VSI: Implementation of Sine-triangle and SVPWM withTMS320LF2407 DSP using the concept of imaginary switching time

Control of BLDC Motor: Principle of operation with Drive control system, implementation of control system using TMS320LF2407 DSP

Control of PMSM: Principle of operation with drive control system, implementation of vector control using TMS320 LF2407DSP

Control of Induction Motor: Implementation offield oriented control for the speed control of Induction Motor using TMS320LF2407 DSP.

Text Books:

1. Hamid A. Toliyat: DSP Based Electromechanical Motion Control, 1st Edition, CRC Press, 2004
2. Ned Mohan, T.M. Undeland and William P. Robbins: Power Electronics: Converters, Applications, 3rd Edition, John Wiley & Sons, 2009

Reference:

1. Application Notes from the website of Texas Instruments

EE5263	**Flexible AC Transmission Systems**	**3 – 0 – 0**	**3 Credits**

Course Outcomes:

CO1	Understand the need for control of power flow and identify methods for it
CO2	Analyse the performance of VSCs to control real power, reactive power and harmonics
CO3	Analyse the performance of Series, Shunt and combined controllers
CO4	Improve the performance of power systems with FACTS controllers

Introduction to FACT Systems: Need for power system interconnections, Evolution of AC and DC transmission systems, Comparison of HVDC and HVAC Transmission systems, power flow in AC systems, Relative importance of controllable parameters, Basic types of FACTS controllers, shunt and series controllers

Converter Topologies& Control Strategies for FACT devices: Current source and Voltage source converters, Harmonics in 3-phase bridge converter, 12 pulse and 24 pulse converters, Pulse width modulation techniques, Elimination of harmonics and voltage control

Objectives of shunt compensation, Methods of controllable VAR generation, Static Var Compensator, its characteristics, TCR, TSC, FC-TCR configurations, STATCOM, basic operating principle, control approaches and characteristics

Objectives of series compensator, variable impedance type of series compensators, switching converter type compensators, TCSC, TSSC- operating principles and control schemes, SSSC, Power Angle characteristics, Control range and VAR rating

Static Phase Angle Regulators – power flow control by phase angle regulator, improvement of transient stability, power oscillation damping, Switching converter based Voltage and Phase angle regulator,

Unified Power Flow Controllers: Introduction, Basic operating principles, Conventional control capabilities, Control structure of UPFC, Interline power flow controller

Text Books:

1. Understanding FACTS – Concepts and Technology of Flexible AC Transmission Systems,NarainG.Honorani, Laszlo Gyugyi

2. Flexible AC Transmission Systems (FACTS), Yong Hua Song & Allan T Johns

EE5191	**Seminar - II**	**0 – 0 – 2**	**1 Credit**

Course Outcomes:

CO1	Understand advanced topics in power electronics & drives
CO2	Improve language and communication skills

EE6142	**Comprehensive Viva–Voce Examination**	**0 – 0 – 0**	**2 Credits**

Course Outcomes:

CO1	To comprehend and correlate the understanding of various courses in design and operation of modern power electronics & drive systems.

EE6149	**Dissertation Part–A**	**0 – 0– 0**	**6 Credits**

Course Outcomes:

CO1	Recognize and formulate a problem to analyze, synthesize, evaluate, simulate and create a power electronic converter and/or a drive system.
CO2	Carryout modeling and simulation studies pertaining to the system and prepare a presentation

EE6199	**Dissertation Part–B**	**0– 0 – 0**	**12Credits**

Course Outcomes:

CO1	Build the hardware to demonstrate the principle of working
CO2	Correlate the analytical, simulation and experimental results
CO3	Deduce conclusions and draw inferences worthy of publication