COURSE STRUCTURE & SYLLABUS

OF

M TECH POWER ELECTRONICS AND ELECTRICAL DRIVES(PEED)

(EFFECTIVE FROM 2019-20 ACADEMIC SESSION)

COURSE STRUCTUREFOR M.TECH PROGRAMME IN

POWER ELECTRONICS AND ELECTRICAL DRIVES(PEED)

Course No.	Course Name	L	T	P	C
	Semester - 1				
EEC508	Power Electronic Converters	3	0	0	9
EEC502	Modelling of Electrical Machines	3	0	0	9
EEC503	Numerical Simulation for Electrical Engineering	3	0	0	9
EEC504	Advanced Control System	3	0	0	9
EEC509	Converter Controlled Machine Drives	3	0	0	9
EEC506	Advanced Electrical Machine Lab	0	0	3	3
EEC510	Advanced Power Electronics Lab	0	0	3	3
	Total	**15**	**0**	**6**	**51**

Course No.	Course Name	L	T	P	C
	Semester -2				
EEDXXX	D. Elective 1	3	0	0	9
EEDXXX	D. Elective 2	3	0	0	9
EEDXXX	D. Elective 3	3	0	0	9
EEC511	Renewable Energy Sources	3	0	0	9
EEC512	Soft Computing Techniques	3	0	0	9
EEC515	Advanced Power Electronics and Drives Simulation Lab	0	0	3	3
EEC516	Advanced Drives Lab	0	0	3	3
	Total	**15**	**0**	**6**	**51**

Course No.	Course Name	L	T	P	C
	Semester - 3				
EEC523	Thesis Unit 1	0	0	0	9
EES524	Thesis Unit 2	0	0	0	9
EES525	Thesis Unit 3	0	0	0	9
EES526	Thesis Unit 4	0	0	0	9
	Total	**0**	**0**	**0**	**36**

Course No.	Course Name	L	T	P	C
	Semester - 4				
EEOXXX	D. Elective 4	3	0	0	9
EEOXXX	D. Elective 5	3	0	0	9
EEC527	Thesis Unit 5	0	0	0	9
EEC528	Thesis Unit 6	0	0	0	9
	Total	**0**	**0**	**0**	**36**

Departmental Electives: (II SEMESTER)

Course No.	Course Name	L	T	P	C
			Semester - 4		
EED501	Design of Power Converters	3	0	0	9
EED502	Advanced Machine Drives	3	0	0	9
EED503	Digital Control of Power Electronics & Drives	3	0	0	9
EED504	Wireless Power Transfer	3	0	0	9
EED505	Power Electronics for Renewable Energy Systems	3	0	0	9
EED506	High Power Converters	3	0	0	9
EED513	Power Quality	3	0	0	9

Open Electives: (IV SEMESTER)

Course No.	Course Name	L	T	P	C
			Semester - 4		
EEO501	Smart Grid Technology	3	0	0	9
EEO502	Industrial Instrumentation	3	0	0	9
EEO503	Electric & Hybrid Electric Vehicles	3	0	0	9
EEO504	Condition Monitoring of Electrical Machines	3	0	0	9

<u>Total Theory papers</u>

Departmental Core: 07
Departmental Elective: 03
Open Elective: 02
Total practical papers: 04
Thesis Units: 06

SEMESTER 1		
EEC508	**Power Electronic Converters**	**(3-0-0)**

Course Philosophy:

The Syllabus is concerned with understanding, modelling and analysing power electronic converter. The topics covered are necessary to understand working principle of power electronic systems.

Learning outcomes:

The students should become capable to analyse and model a power converter and find out associated idealized waveforms as per the working principle. They should be able to identify component rating and design a closed loop system.

Module 1: **[4L]**

Review: Brief Introduction to Components in Power Electronics, Calculation of Losses and Cooling, Uncontrolled and Phase controlled rectifiers.

Module 2: **[15L]**

DC to DC Converter: Modelling and operating principles of Non-isolated DC-DC converter topologies, Isolated DC-DC converter topologies, Small signal modelling, Control of DC-DC converter, Soft-switching converters and Applications.

Module 3: **[15L]**

DC to AC Converter: Modelling and operating principles of two-level voltage source inverter (VSI), multi-level VSI, current source inverter (CSI). PWM techniques for the inverters and applications.

Module 4: **[5L]**

AC to AC Converter: Operating principles of AC voltage controllers, Cyclo-converter, Matrix Converter and Applications.

Total 39L

Text books:

- L Umanand , Power Electronics: Essentials & Applications, Wiley.
- R. W. Erickson, Fundamentals of Power Electronics , Springer.

EEC502	Modelling of Electrical Machines	(3-0-0)

Course Philosophy:

Learning Outcome: At the end of the course, the students may be able understand principle of energy conversion, two-pole machines and Kron's primitive machine, mathematical modeling for analysis of different electrical machine, examine the transient behavior of the machine andcurrent trend in machine control in industry

Module 1: Introduction **[5L]**

Singly excited system; Doubly excited system; Types of transformation used in electrical machine modelling; Impedance, torque and motional impedance matrix; Dynamic equations of induction machines; Induction machine in two-phase reference frame; Induction machine in pseudo-stationary reference frame; The primitive machine equations

Module 2: Modelling and Analysis of DC Machine **[9L]**

Voltage-current relationship of different types of dc machine such as separately excited dc machine, dc machine with interpole winding, cumulative compound dc machine, differential compound dc machine; Dynamic equations of DC machines; Small signal model of DC machine; Transient analysis of dc machine

Module 3: Modelling and Analysis of Induction Machine **[10L]**

The arbitrary reference frame; Induction machine equations in arbitrary, synchronous reference frames and small signal modelling; Voltage-current relationship of 3-phase and single-phase induction machine; Steady state equivalent circuit of 3-phase induction motor; Introduction to field oriented control of induction machines; Space vector formulation of induction machine equations; Steady state models of induction machine

Module 4: Modelling and analysis of Synchronous Machine **[15 L]**

Voltage-current relationship of synchronous machine; Derivation of Park's equation; Operational equivalent circuit of synchronous machine; Operational impedances, time constants, steady state operation, phasor and block diagram representation of synchronous machine; Short circuit analysis of synchronous machine; Relevant computer analysis of synchronous machine; Capacitive loading of synchronous machine; Concept of automatic voltage regulator; Pull in operation; Analysis of divided winding rotor synchronous machine; Synchronous machine analysis for power system application such as unbalance short circuit study

Total 39L

Text Books:

- Generalized Theory of Electrical Machines: P.S. Bhimbra
- Generalized Theory of AC Machines: B. Adkins & R.G. Harley

EEC503	Numerical Simulation for Electrical Engineering	(3-0-0)

Course philosophy :

MATLAB is a popular language for numerical computation. This course introduces students to MATLAB programming, and demonstrate its use for scientific computations. The basis of computational techniques are expounded through various coding examples and problems, and practical ways to use MATLAB will be discussed.

Learning outcome:

At the end of the course student will have ability to 1. Express programming & simulation for engineering problems. 2. Write basic mathematical, electrical, electronic problems in MATLAB 6. Simulate basic electrical circuit in Simulink. 3. Connect programming files with GUI Simulink.

Module 1: **[4L]**

An Introduction to MATLAB: MATLAB Fundamentals, MATLAB Environment and Command Window, Saving and re-loading a work, MATLAB demos, Vector and Matrix Manipulation, Scalar Operations, Matrix Operations

Module 2: **[12L]**

Programming in MATLAB: Basics of MATLAB programming structure, Script Files, Functions, Debugging Programs, Creating functions using m-files, Loops, branches and Control flow, Relational and logical operations, Advanced data objects: Multidimensional matrices and structures

Module 3: **[4L]**

MATLAB Graphics: Two and Three-dimensional graphics, Multiple Plots, Axis Scaling, Printing Graphics

Module 4: **[11L]**

Introduction to SIMULINK:

What can SIMULINK be used for? Creating Models, Blocks, Systems and Subsystems

Simulating Dynamic Systems• Solving a Model, Solvers, MATLAB Simulink Integration, SIMULINK and GUIs, SIMULINK Exercises

Module 5: **[8L]**

Introduction to MATLAB Toolboxes: Neural networks, Fuzzy logic, Control System, Optimization Toolbox

Total Lecture Hours [39L]

Text Books:

1. Getting Started with MATLAB : Rudra Pratap
2. MATLAB –an introduction with Applications : Amos Gilat

EEC504	**Advanced Control System**	**(3-0-0)**

Course Philosophy: The syllabus has been revised considering (i) clarity, flow in teaching-learning process and (ii) to include some important topics from non-linear control systems. Underlined bold faced portions are new inclusions whereas only underlined portions are modifications on existing syllabus. Module-3 has gone rigorous revision whereas module-4 is basically inclusion of non-linear control systems in the revised syllabus.

Learning Outcome: This syllabus would act for acquaintance of modern control systems suitable for all specializations in Electrical Engineering and a basis for specialization subjects under Control Systems specialization.

Module1: **[9L]**

Introductory matrix algebra and linear vector space, Linearization, State space representation, Similarity transformation and invariance of system properties due to similarity transformations, Caley-Hamilton theorem. Minimal realization of transfer function.

Module 2: **[11L]**

Solution of state equations, Evaluation of state transition matrix. Controllability and controllable canonical form, Observability and observable canonical form. Discretization of continuous-time state space model, discrete-time models.

Module 3: **[11L]**

Pole placement technique using state feedback and Ackermann's formula. Full order observer and design of full order observer using Ackermann's formula, Duality, Observer based controller design, reduced order observer, Combined controller-estimator compensator, Linear quadratic regulator problem and algebraic Riccati equation.

Module 4: **[8L]**

Non-linear phenomena and characteristics, Linearization, introduction to describing function and phase plane analysis. Stability in the sense of Lyapunov, Lyapunov stability theorem, Lyapunov function for linear systems.

Total 39L

Text Books:

[1] Modern control engineering – K Ogata

[2] Digital control and state variable methods – M GopaL

EEC509	CONVERTER CONTROLLED MACHINE DRIVES	(3-0-0)

Course Philosophy:

Review the role of Power Electronics for modern Electric Drive systems, modelling of Drive components and their steady state analysis, understand the performance of a closed-loop control of a DC, Induction and Synchronous Motor Drives, design of open- and closed-loop controller for an Electrical Drive system.

Learning Outcome:

After completing the course students can able to understand the performance of a open-loop and closed-loop control of a DC and IM, compare their performance, do the modelling of the controller and Design the gain parameters.

Module 1: **[3L]**

Introduction to Electrical Drives: Introduction, Power Devices and switching, Electrical Machines, Power Converters, Controllers, Loads, etc.

Module 2: **[10L]**

Phase Controlled DC Motor Drives: Performance characteristics of different DC motors and load in four quadrants, Modelling of DC Motors and load, Single-phase and three-phase converter controlled DC Motor Drives under continuous and discontinuous conduction, two- and four-quadrant converters for DC Motor Drives, Controller for phase controlled converter, Steady-State analysis of a converter controlled DC Drives. Design of current and Speed Controller, Industrial Applications.

Module 3: **[6L]**

Chopper Controlled DC Drives: Four-quadrant Chopper for a DC motor under different Quadrants, Steady-State analysis of a chopper fed DC motor for continuous and discontinuous conduction mode, Closed-loop operation, Modelling and Design of Current Controllers, Industrial Applications.

Module 4: **[5L]**

Phase Controlled Induction Motor (IM) Drives: Performance of a 3-phase IM under stator voltage control, Closed-loop operation of IM under voltage control and Slip Energy Recovery Scheme. Effects of Harmonics on the IM performance.

Module 5: **[10L]**

Frequency Controlled IM Drives: Performance of a 3-phase IM under variable voltage and frequency operation, Constant v/f Control of IM under open- and closed-loop, pulse width modulation (PWM) techniques for IM drives, CSI based IM Drives, introduction to vector control, Industrial Applications.

Module 6: **[5L]**

Synchronous Motor Drives: Introduction and characteristics of different synchronous motor, Synchronous motor drives using variable frequency control, Introduction to Permanent Magnet AC motor drives.

Text books:

1) Electric Motor Drives-Modelling, Analysis and Control- By R. Krishnan, Prentice Hall of India
2) Modern Power Electronics and AC Drives- By Bimal K. Bose, Prentice Hall, PTR.

EEC506 Advanced Electrical Machines Laboratory 0-0-3

1. Sensor-less vector control of Induction Motor
2. DC shunt motor speed control using 3-φ half wave converter
3. DC shunt motor speed control using 3-φ full wave converter
4. DC shunt motor speed control using 3-φ four quadrant chopper
5. Study of Scott connected transformer.
6. Study of speed control of three-phase squirrel cage induction motor by V/f method.
7. Determination of direct axis reactance (X_d) and quadrature axis reactance (X_q) of a 3-φ salient pole synchronous machine.
8. Measurement of negative sequence reactance of a three-phase alternator.
9. Study of parallel operation of two transformers belonging to different vector groups.
10. Study of zig- zag connection of transformer.

EEC510 Advanced Power Electronics Lab 0-0-3

1. Experimental study of static and dynamic characteristics of SCR, MOSFET and IGBT. Analysis of waveform of switch voltage and current. Calculation of switching and conduction loss. Modelling of device in PSPICE.
2. Experimental study of Gate Drive circuit for an IGBT. Analysis of waveform, design of isolated gate drive circuit and design of shoot through fault protection.
3. Design, verification and characterization of voltage, current sensors and speed sensors for power electronic or drive systems.
4. Design of inductor for high frequency power electronic circuit. Experimental validation and loss estimation for the designed inductors.
5. Experimental study of SCR based three phase controlled rectifier with DC motor load. Comparison of experimental result with simulation results obtained from MATLAB/ PSIM/PSPICE based software models.
6. Experimental study on non-isolated and isolated types of DC-DC converter. Verification of steady state operating principle, estimation of efficiency and evaluation of different components.
7. Experimental study on different PWM techniques for single-phase and three-phase Voltage Source Inverter (VSI) with R-L type load. Comparison of experimental result with simulation results obtained from MATLAB/ PSIM/PSPICE based software models.

8. Experimental study on four quadrant DC-DC converter with DC motor load. Comparison of experimental result with simulation results obtained from MATLAB/ PSIM/PSPICE based software models.
9. Experimental study on soft switching converter operation. Verification of steady state operating principle, estimation of efficiency and evaluation of different components. Comparison of experimental result with simulation results obtained from MATLAB/ PSIM/PSPICE based software models.
10. Experimental study on different multilevel inverter setup. Measurement of output voltage, current harmonics and estimation of efficiency.
11. Study of commercially available power electronic converter systems such as UPS/Chopper/ Electric Drive/ Grid Connected VSI.

SEMESTER II

EED501	**DESIGN OF POWER CONVERTERS**	**(3-0-0)**

Course Philosophy:
Review the operation of various power converters, analysis of Power Electronic converters, design aspects and their rating of the devices for various applications are also covered.

Learning Outcome:
To analysis of the theoretical aspects of different converters and inverters.
Understand the design aspects and components selection of a converters.
Understand the Control aspects of the converters for simulation and implementation.

Module 1: **[7L]**

Design aspects of AC to DC uncontrolled and controlled converters: Performance analysis of Line frequency single-phase and three-phase AC-DC converter under constant current load, Harmonic analysis of output voltage and input current under constant current load, selection of components for the design of single-phase and three-phase rectifiers, Design of filter circuit, Industrial Applications.

Module 2: **[6L]**

DC to DC Switch Mode Power Converters and their Design: Introduction, steady state analysis of buck, boost, buck-boost and cuk converter under continuous and discontinuous mode of operation, steady state analysis of full-bridge DC-DC converter, components selection for the design of DC-DC converter and filters, Design of PWM techniques, Industrial Applications.

Module 3: **[9L]**

Design of Switch Mode DC-AC Inverters: Analysis of the performance of a single-phase switched mode inverter under PWM and square wave mode, their harmonic analysis. Performance analysis of a Three-phase inverter under PWM and square wave modes, their harmonic analysis, Selection of components for the design of single-phase and three-phase inverter components, Industrial Applications.

Module 4: **[5L]**

Design of Thermal and Magnetic Components: Introduction, modes of heat transfer, thermal model of power devices, Selection of heat sinks. Magnetic materials, hysteresis and eddy current losses in core, selection of parameters for the design of a magnetic components for Power Electronic Applications, thermal consideration, design steps of inductor.

Module 5: **[4L]**

Design of Drive Circuit for the Power Semiconductor Switches: Turn-on and Turn-off Characteristics of semiconductor switches, Drive circuits for different power semiconductor switches, Design of snubber circuit.

Module 6: **[4L]**

Un-interrupted Power Supply (UPS) Design: Basic configuration of UPS, components of UPS, transformer free UPS design, etc.

Total 39L

Text books:

1) Power Electronics Converters, Application and Designî - Mohan N. Undeland . T & Robbins W John (Wiley), 3 rd edition, 2002
2) Power Electronics Essentials & Applications, L. Umanand (J Wiley)

EED502	Advanced Machine Drives	(3-0-0)

Course Philosophy:

Review the concepts and basic operation of electric drive systems. Understand closed loop operation of dc, induction and synchronous machine drives.

Understand the design techniques of drive systems.

Learning Outcome: At the end of the semester students will gather knowledge about the functioning, control and orientation of various types of machines

Module 1: **[2L]**

Introduction:

Generalized theory and Kron's primitive machine model.

Module 2: **[8L]**

Modeling of Machines:

Modeling of dc machines, Modeling of induction machine, Modeling of synchronous machine, Reference frame theory and per unit system.

Module 3: **[14L]**

Control of Induction Motor Drive:

Scalar control of induction motor, Principle of vector control and field orientation, Sensorless control and flux observers, Direct torque and flux control of induction motor, Mutilevel converter-fed induction motor drive, Utility friendly induction motor drive.

Module 4: **[8L]**

Control of Synchronous Motor Drive:

Self-controlled synchronous motor, Vector control of synchronous motor, Control of synchronous reluctance motor.

Module 5: **[7L]**

Control of Special Electric Machines Drives:

Permanent magnet synchronous motor, Brushless dc motor, Switched reluctance motor, Stepper motors and control.

Total: 39L

Text Books:

1. P. Vas, "Sensorless Vector and Direct Torque Control", Oxford University Press, 1998.
2. Analysis of Electric Machinery and Drive Systems - P. Krause, O. Wasynczuk, S.D. Sudhoff.

ED503	Digital Control of Power Electronics and Drives	(3-0-0)

Course Philosophy:

The Syllabus is aimed to achieve through understanding on application of digital control theory in the field of Power Electronics. The topics covered are necessary for design, operation, control and protection of power electronic converter.

Learning outcomes:

The students should become capable to analyse and model a power electronic system. They should be able to design a closed loop system in discrete domain and know essentials to implement different algorithm on digital controller platform.

Module 1: **[2L]**

Basic concepts and definitions:

Requirement of digital control in power electronics, Different types of power converters and available digital controllers.

Module 2: **[5L]**

Review of control theory:

Representation of systems in digital domain, Laplace transform, Z transform, Digital Filter, Mapping between s-plane and z-plane, Effect of sampling, Continuous to discrete domain conversion, Control system performance requirements; ADC and DAC; ZOH and FOH.

Module 3: **[9L]**

Discrete domain computation:

Numeric formats: Fixed point and floating point systems, Operations like addition, subtraction, multiplication and division; Normalization and scaling, Algorithms for calculating Reciprocal, Square root, Sine and Cosine, Exponential, Logarithm etc.; Implementation of PI controller with anti-windup, PWM generation etc.

Module 4: **[9L]**

System Modelling:

Transfer function, Differential equation linearization, State space representation, Transfer function modelling of a DC motor, Circuit averaging and small signal modelling, Space vector modelling of Induction Motor.

Module 5: **[14L]**

Controller design:

Controller design techniques, Bode diagram method, Root locus method, State space method, Full state feedback, Estimator design, Digitally controlled DC-AC, AC-DC, DC-DC and AC-AC converters; Open loop control and closed loop control of Power Converter.

Total 39 L

Text books:

- L Umanand, Power Electronics: Essentials & Applications, Wiley.
- G. F. Franklin and J. D. Powell, Digital Control of Dynamic Systems, Pearson.

EED504	Wireless Power Transfer	(3-0-0)

Course philosophy :

- Wireless Power Technologies (WPT) holds the promise of freeing us from the tyranny of power cords. This technology is being incorporated into all kinds of devices and systems. This course explains the fundamental principles and latest advances in WPT and illustrates key applications of this emergent technology.

Learning outcome:

- The fundamental principles of WPT for cable-free transfer of power
- Theories for inductive power transfer (IPT) based on the coupled inductor model and low-order circuit compensation
- Specific converter topologies for lighting and battery charging applications

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Module 1: **[2L]**

Basic Circuit Theory: Review of transformers. Leakage inductance. Circuit compensation principles. Low-order compensations; series and parallel compensations. Resonance and operating frequency. Efficiency equation.

Module 2: **[8L]**

Power Converters Fundamentals: Power Converters Fundamentals DC-DC converters. AC-DC converters and inverters. PWM and soft switching principles. Basic topologies with transformers. Input, output and transfer characteristics of power converters. Incorporation of leaky transformer. Control methods.

Module 3: **[13L]**

Compensation Configurations: Types of compensation for inductor power transfer. Characteristics for various termination requirements. Design for load-independence output voltage and output current. Efficiency optimization.

Module 4: **[8L]**

Applications: Circuit requirements for various loading conditions. Characteristics of LED loads, resistors and battery loads. Appropriate compensation design. Lighting systems. Battery charging profiles. Electric vehicle charging. Energy efficiency metric for charging.

Module 5: **[8L]**

Technology Trends: Demand for safe power transfer and durable operation. Portable and smart devices. Mobile communication devices. IoT devices and systems. Sensors. Solidstate lighting development. Battery technologies. Electric vehicle development. Renewable source integration trends. Future trends and demand for wireless power transfer.

Total 39L

Text Books:

1. Philip T. Krein, "Elements of Power Electronics", Oxford University Press, USA, **ISBN-10:** 0195117018
2. J. I. Agbinya, "Wireless Power Transfer", River Publishers, 2015.

EED505	POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS	3-0-0

Course Philosophy:

Different MPPT techniques and control technique using power electronic converters is the important components of the major renewable energy extractions. However the present course is also focused on the familiarizations different grid synchronization techniques, filtering etc.

Learning outcome:

At the end of the course, students should able to

- Understand the operation of photovoltaic and wind energy systems and their control.
- Understand the grid synchronisation techniques with the renewable energy sources
- Understand the maximum power Point (MPP) technique and the grid current control techniques.

Module 1 : **[4L]**

Introduction to Renewable Energy sources: Review of renewable energy technology, Requirements of the grid for renewable energy systems.

Module 2 : **[8L]**

Solar Energy Extractions:

PV system configurations, Solar cell technologies, Maximum power point tracking, DC-DC converters, conventional and multilevel converters and their PWM control strategies.

Module 3 : **[8L]**

Wind power Extractions:

Wind power energy system, types of wind turbines, fixed speed and variable speed operation, Grid converters for wind power, control of converters for wind power extraction.

Module 4 : **[9L]**

Grid synchronization:

Grid synchronisation techniques for single-phase and three-phase renewable energy system, Islanding operation, grid filters.

Module 5 : **[6L]**

Grid Current Control: Current control technique, Control of converters for fault-ride operation.

Module 6 : **[4L]**

Storage Systems:

Configuration of battery energy and Fuel cells storage systems, sizing of storage elements, energy management and control.

Total 39 L

References:

a. Remus Teodorescu, Marco Liserre and Pedro Rodríguez, Grid Converters for Photovoltaic and Wind Power Systems , 2011 John Wiley & Sons, Ltd.
b. Hybrid & Electric Vehicles, CRC Press, Taylor and Francis Power Electronics – Daniel W. Hart

EED506	**High Power Converters**	**(3-0-0)**

Course Philosophy:

The Syllabus is concerned with understanding, modelling, operating constraints and steady state analysis of high power converter.

Learning outcomes:

Understanding of operating principle, constraints and techniques involved at high power application of different power electronic converters. To be able to perform steady state analysis of such power electronic systems.

Module 1: **[3L]**

Introduction:

Technical requirements and challenges, Power converter configurations, Applications.

Module 2: **[3L]**

High power semiconductor devices:

Ratings and characteristics of available power semiconductor devices for high power applications, Operations of series connected device, causes of voltage unbalance and voltage balancing.

Module 3: **[12L]**

AC to DC conversion:

Multi-pulse Diode Bridge and SCR rectifier (6, 12, 18 and 24 pulse rectifiers) – Circuit configuration, operating principle, influence of line and leakage inductances, PF and THD at AC side; Phase shifting transformers; PWM Current source rectifier.

Module 4: **[15L]**

DC to AC conversion:

Two level Voltage Source Inverter (VSI), PWM Methods; Diode-Clamped Multilevel Inverters, Cascaded H-Bridge Multilevel Inverters, Neutral Point Clamped (NPC) H-bridge Inverter, Flying Capacitor Multilevel Inverter, PWM Methods; PWM current source inverter.

Module 5: **[6L]**

Applications:

Medium Voltage motor drives, HVDC transmission and other suitable applications.

Total 39L

Text books:

- Bin Wu-High Power Converters and AC Drives, Wiley.
- D. G. Holmes and T. A. Lipo, Pulse Width Modulation for Power Converters, Wiley.

EED513	Power Quality	(3-0-0)

Course philosophy:

This course identifies and analyzes various power quality issues such as voltage sag, voltage unbalance, transient overvoltage, voltage and current harmonics arising out in today's mixed form of generation. This also imparts knowledge about various mitigation technologies. Power quality of electricity supply networks against major international standards, are assessed by students.

Learning outcome:

- Review of power quality issues in power system.
- Acquaintance with devices which mitigate power quality problems.
- Understanding various design and control techniques.

Module 1: **[6 L]**

Brief review of various power quality (PQ) problems: Source of generation and their impacts on equipment and systems, need of monitoring, international power quality standards.

Module 2: **[8 L]**

Control of harmonics using passive L-C filters, tuned and de-tuned filters, their design criterion and implementation.

Module 3: **[14 L]**

Power factor improvement, reactive power compensation, mitigation of harmonics and voltage sag compensation using active power filters. Study of various active power filters viz., static shunt compensators (STATCOM), dynamic voltage restorer (DVR), unified power quality conditioner (UPQC), etc.

Module 4: **[11 L]**

Suitability of type of active filters for mitigation of various power quality problems, Design of active power filters, various topologies and control schemes.

Total [39L]

Text Books:

1. Arindam Ghosh and Gerard Ledwich *'Power Quality Enhancement Using Custom Power Devices (Power Electronics and Power Systems)'*, Springer; 2002.
2. Surya Santoso, H. Wayne Beaty, Roger C. Dugan, and Mark F. McGranaghan, *'Electrical Power Systems Quality'*, McGraw-Hill Professional, 2002.

EEC511	Renewable Energy Sources	(3-0-0)

Course philosophy :

The world faces large challenges in providing clean, efficient and cost effective power supply for its population. The growing need of energy will be met in harmony with nature and society. Majority will be fulfilled through the participation of renewable sources of energy. It is one of the main tasks of this century. Hence, the demand of expert in energy and earth resources is the need of an hour.

Learning outcome:

Importance of renewable energy resources and their types

Getting acquainted with basic design and working principle behind small hydro, solar, biomass, wind energy systems and other.

Module 1: **[3L]**

Energy sources & demand in different sectors, Conventional & Non-conventional energy sources; Importance of new and renewable energy sources in the present energy scenario and type of resources

Module 2: **[7L]**

Small hydro power potential and classification of SHP projects; Basic components of civil works; Selection of electro-mechanical equipment; mini/micro-hydel, Pump-storage plant and electric power generation from tidal Energy

Module 3: **[7L]**

Estimation of Biomass resources, Biomass Technologies for thermal and biological conversion; Biomass based Electricity Generation and application of bio-fuels.

Module 4: **[8L]**

Solar Energy estimation and different routes of solar energy applications; Technologies for solar thermal power generation and Storage; Photovoltaic power generation system; Applications.

Module 5: **[9L]**

Estimation of wind energy potential and site selection; Types of wind mills, their basic characteristics and applications; Recent Technologies of wind energy conversion system (WECS), wind farms.

Module 6: **[5L]**

Ocean energy-potential, method of harnessing; Geothermal Energy; New technologies for renewable energy; Integrated renewable energy systems.

Total [39L]

Text Books:

1. Godfrey Boyle, (Editor) "Renewable Energy Power for a Sustainable Future", 2nd Edition, Oxford University Press.
2. J. Twidell and T. Weir, "Renewable Energy Resources", E & F N Spon Ltd, London, 1986.

EEC512	Soft Computing Techniques	(3-0-0)

Course Philosophy:

Introduction to neural network, fuzzy logic and implementation of other classical soft computing and evolutionary algorithms in solving complex constrained electrical engineering problems related to load flow, reactive power planning, economic load dispatch, decision making etc.

Learning Outcome:

At the end of the course, the students will be able to implement MATLAB in solving power system problems such as formation of Y-Bus Matrix, load flow problems and complex constrained problems such as Economic Load Dispatch and reactive power planning using soft computing techniques like GA, PSO etc.

Module 1: Neural network: Mathematical model of neurons, ANN architecture; Learning rules: supervise, unsupervised and reinforced learning **[8L]**

Module 2:ANN training algorithms; Hebbs rule and hebbian learning; perceptron model; back propagation algorithm; associative memories; Boltzman machine **[8L]**

Module 3: Fuzzy logic: Introduction to fuzzy logic, classical sets and fuzzy sets, membership function, fuzzy rule generation, operations on fuzzy sets, fuzzification, defuzzification **[12L]**

Module 4: Evolutionary programming: Genetic Algorithms, Particle swarm optimization method, Differential evolution technique, Tabu search, ant colony based optimization method **[11L]**

Total: 39L

Text books:

- Goldberg, “Genetic algorithms” Pearson Education India; 1st edition (1 December 2008)
- Rao, Singiresu S. *Engineering optimization: theory and practice*. John Wiley & Sons, 2009.

EEC516 Advanced Drives Lab 0-0-3

List of Experiments:

2. Experimental study of a DC motor drives under open-loop and Closed-loop control.
3. Experimental study of a three-phase induction motor (IM) drives under open-loop and Closed-loop control.
4. Experimental study of a vector controlled three-phase induction motor (IM) drives.
5. Experimental study of a direct torque controlled based three-phase induction motor (IM) drives.
6. Experimental study of a vector controlled three-phase permanent magnet synchronous machine (PMSM) drives.
7. Experimental study of a vector controlled three-phase brushless DC (BLDC) machine drives.
8. Study and experimental verification of different PWM techniques for a three-phase two-level voltage source inverters (VSI).
9. Study and experimental verification of different PWM techniques for a three-phase multilevel-level voltage source inverters (VSI).
10. Experimental study of a switched reluctance machine drives.
11. Experimental study of a multilevel inverter based three-phase induction motor (IM) drives.
12. Study of commercial/industrial drives systems such as Electric Drive/ VSI.

EEC515 Advanced Power Electronics and Drives Simulation Lab 0-0-3

List of Experiments:

1. Study and development of a MATLAB/Simulink based model for a single-phase diode-rectifier and three-phase diode rectifier connected with a highly inductive load. Analyze the harmonics &THD of input current, power factor. Also find the ripple factor of the output voltage. Compare the simulation results with theoretical one.
2. Study and development of a MATLAB/Simulink based model for a step-down and step-up DC-DC converter fed to an inductive load (RLE load). Analyze the waveforms of inductance current and voltage for a PWM mode (continuous and discontinuous mode of operation). Compare the simulation results with theoretical one.

3. Study and development of a MATLAB/Simulink based model for a single-phase VSI operating under square wave mode. Find the harmonics &THD of output voltage under this mode. What are the improvements if the VSI is operating under sinusoidal PWM mode (bi-polar as well as unipolar techniques)? Compare the simulation results with theoretical one.

4. Study and development of a MATLAB/Simulink based model of a three-phase VSI operating under 180^0 mode for an inductive load. Find the harmonics &THD of output line voltage. What are the improvements if the inverter is operating under sinusoidal PWM model? Compare the simulation results with theoretical one. How third harmonic injection in the PWM control signal improves its performances?

5. Study and development of a MATLAB/Simulink based model of a sinusoidal PWM technique for a single-phase and three-phase five-level inverter (NPC/CHB) using level-shifted PWM and phase-shifted PWM techniques with and without 3^{rd} harmonic injection.

6. Study and development of a MATLAB/Simulink based model of a three-phase, three-level/five-level VSI (NPC/CHB) based 3-phase IM drives under open loop control operating under level-shifted PWM and phase-shifted PWM techniques. Analyze the harmonics &THD under the above techniques.

7. Study and development of a MATLAB/Simulink based model of a three-phase, three-level/five-level inverter for a three-phase induction motor drives under closed-loop constant v/f techniques. Show the speed response under variable speed/variable load torque operation.

8. Study and development of a MATLAB/Simulink based model of a PV array having 500W DC load. Using the standard equations of PV source draw its I-V & P-V characteristics under various parameters like irradiation & temperature.

9. Study and development of a MATLAB/Simulink based model of the above PV system operating under perturbed & observed (P&O) method of MPPT. Measure the output power under different weather conditions.

10. Study and development of a MATLAB/Simulink based model of a Grid-tied PV system operating under perturbed & observed (P&O) method of MPPT. Measure the output power under different weather conditions.

	Semester- IV	
EEO501	**Smart Grid Technology**	**(3-0-0)**

Course philosophy :

The topics of the course focus on basic concept of Smart Grid, various types of smart-grid devices that are used in the power industry. Emphasis is placed on the operation, installation and demand side management of smart-grid devices and systems

Learning outcome:

After learning the course the students should be able to:

• Know what a function of smart grid is, what is the futuristic grid. • Issues while implementing the smart grid approach. • Concept of Microgrid and distributed generation. • Need of communication technology in smart grid.

Module 1: **[2L]**

Introduction to Smart Grid-I, Introduction to Smart Grid-II, Architecture of Smart Grid, Smart Grid standards and policies, Smart Grid control layer and elements

Module 2: **[6L]**

Distributed generation resources- I, Distributed generation resources- II, Smart Grid components control elements, Smart Grid Technologies, Plug-in-Hybrid Vehicles (PHEV)

Module 3: **[4L]**

State Estimation for low voltage networks, Smart Grid Monitoring, Phasor measurement units, Phasor estimation, Dynamic Phasor estimation

Module 4: **[5L]**

Islanding detection –I, Islanding detection –II, Islanding relays, Fault Detection, Isolation, and Service Restoration., Digital relays for Smart Grid protections; relay co-ordination.

Module 5: **[6L]**

Modelling of AC Smart Grid components-I, Modelling of AC Smart Grid components-II, Modelling of DC Smart Grid components-I, Modelling of DC Smart Grid components-II, Modelling of storage device

Module 6: **[5L]**

Operation and control of AC Smart Grid-I, Operation and Control of AC Smart Grid-II, Operation and control of DC Smart Grid-I, Operation and Control of DC Smart Grid-II, Simulation and case study of AC microgrid

Module 7: **[5L]**

Simulation and case study of DC microgrid, Operation and control of hybrid Smart Grid-I, Operation and control of hybrid Smart Grid-II, System analysis of AC/DC Smart Grid, Simulation and case study of hybrid microgrid

Module 8: **[6L]**

Demand side management of Smart Grid, Demand response analysis of Smart Grid, Energy Management, Design and Practical study of Smart Grid test bed, Conclusions

Total 39L

References

1. Smart power grids by A Keyhani, M Marwali.

2. Microgrids Architecture and control by Nikos Hatziargyriou

EEO502	**Industrial Instrumentation**	**(3-0-0)**

Course Philosophy:

Modern instrumentation technique is the heart of any industrial process control system. However the present course if primarily focused on the familiarizations and applications of modern instrumentation technique in power system and electrical drives applications.

Learning Outcome:

At the end of the course, students should able to

- Understand the basic theories of advanced sensors and transducers.
- Understand the modern Instrumentation technique presently adopted in Power system and Electric drives related industries
- Design Instrumentation system along with necessary signal processing circuits for Power system and Electric drives related applications

Module 1 **[6L]**

Introduction and design of signal conditioning circuits for various resistive, capacitive, inductive and piezoelectric transducer

Module 2 **[6L]**

Principles and applications of RTD, Thermocouple, Thermistors, Radiation Pyrometer.

Module 3 **[6L]**

Vibration transducer, Magnetostrictive transducer, Pressure and flow transducer, Torque transducer, DP transmitters

Module 4 **[8L]**

Instrumentation amplifiers and isolation amplifiers, Smart and intelligent transmitters, Microcontroller based instrumentation system, Photo electric transducer and its application, SCADA

Module 5 **[7L]**

High energy arc ignition system and flame monitoring, Flue gas analyzer, Hydrogen purity meter, Measurement techniques for water quality parameters.

Module 6 **[6L]**

Optical instrumentation for electrical and mechanical quantities related to electrical machines and power system application

Total **39L**

References:

1. Measurement system- Doebelin , Mc-Grawhill
2. Transducers and Instrumentation- D V S Murty, PHI

EEO503	Electric and Hybrid Electric Vehicles	**(3-0-0)**

Course Philosophy:

Covers various environment friendly transportation systems, components, their connections for hybrid electric and electric propulsion system, motor drives for electric vehicles, energy storage system for vehicle and their energy management,

Learning Outcome:

1. Understand the need and significance of Electric and Hybrid Electric Vehicle
2. Understand the fundamental concepts, operation and analysis of hybrid and electric vehicles
3. Understand the applications of Electric Drives for Electric Vehicles.
4. Understand the role of energy storage and their management.

Module 1: **[4L]**

Introduction to Hybrid Electric Vehicles: History and importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies.

Module 2: **[6L]**

Vehicle Fundamentals:

General Description of Vehicle Movement, Vehicle Resistance, Dynamic Equation, Tractive forces, Vehicle Power Plant and Transmission Characteristics, Vehicle Performance. Longitudinal Vehicle Dynamics, Acceleration Performance and Vehicle Power, Dynamic, Modelling of Vehicle Components, Driving cycle.

Module 3: **[6L]**

Hybrid and Electric and Plug-in Electric Vehicle: Configurations of Electric Vehicles (EV), Performance of EV, Hybrid Electric Vehicle (HEV), Architectures of HEV, Vehicle batteries and its modelling, Battery operated EV, Plug-in EV.

Module 4: **[12L]**

Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives, configuration and control of Permanent Magnet Motor drives, Configuration and control of Switch

Reluctance Motor drives, drive efficiency.

Module 5: **[7L]**

Energy Storage: Introduction to Energy Storage Requirements in Hybrid and 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.

Module 6: **[5L]**

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

Total 39L

Text books:

1) Modern Electric, Hybrid Electric, and Fuel Cell Vehicles Fundamentals, Theory, and Design- Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay and Ali Emadi, CRC PRESS.
2) Hybrid & Electric Vehicles, CRC Press, Taylor and FrancisPower Electronics - Daniel W.

EEO504	Condition Monitoring of Electrical Machines	(3-0-0)

Course philosophy:

Condition monitoring of electrical machines has been gaining increased importance as most of the engineering processes are automated and manpower is reduced. However, electrical machinery receives attention only at infrequent intervals. This is mostly done either when a plant is shut down or protective relay senses faulty machine. This also leads to an unexpected downtime of certain industrial process. Hence, the syllabus is framed with an aim to impart some key ideas on different aspects of condition monitoring such as its importance (Module 1), root cause (Module 2), tools for detection (Module 3,4) and different methods of monitoring (Module 5).

Learning outcome:

The course covers most of the conditional monitoring aspects of electrical machines and would be helpful in developing basic research skills of the students. The course would also be of interest for practicing engineers.

Module 1: **[5L]**

Condition monitoring: Importance of condition monitoring of electrical machines; Objectives of condition monitoring; Generalized scheme of condition monitoring;

Module 2: **[8L]**

Different health hazards and failure modes of electrical machines: Winding insulation failure (both stator and rotor), core faults (both stator and rotor), bearing damages; Classification of faults;

Module 3: **[8L]**

Fundamentals of condition monitoring: Quantities suitable for condition monitoring; instruments used for condition monitoring of electrical machines.

Module 4: **[8L]**

Different basic tools of condition monitoring: Fast-Fourier transform (FFT), Wavelet Transform (WT), Short-Time Fourier transform (STFT).

Module 5: **[10L]**

Different methods of condition monitoring of Induction Motor: Motor current signature analysis, motor vibration signature analysis, motor flux signature analysis, motor power spectral density analysis, Advanced methods of condition monitoring and fault classification:

Total 39L

Recommended Books:

[1] Condition Monitoring of Rotating Electrical Machines by Peter Tavner, Li Ran, Jim Penman, Howard Sedding, IET Digital Library.
[2] Machinery Condition Monitoring: Principles and Practices by Amiya R. Mohanty, CRC Press.