COURSE STRUCTURE & SYLLABUS

OF

M TECH **POWER SYSTEM ENGINEERING (PSE)**

(EFFECTIVE FROM 2019-20 ACADEMIC SESSION)

Course Structure for 2 Year M.Tech Program in Power System Engineering (PSE)

Course No.	Course Name	L	T	P	C
Semester - 1					
EEC501	Power System Analysis	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
EEC505	HVDC transmission and FACTS	3	0	0	9
EEC506	Advanced Electrical Machine Lab	0	0	3	3
EEC507	Advanced Power System 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
EEC513	Advanced power System Simulation Lab	0	0	3	3
EEC514	Advanced Power System Protection Lab	0	0	3	3
	Total	**15**	**0**	**6**	**51**

Course No.	Course Name	L	T	P	C
Semester - 3					
EEC517	Thesis Unit 1	0	0	0	9
EEC518	Thesis Unit 2	0	0	0	9
EEC519	Thesis Unit 3	0	0	0	9
EEC520	Thesis Unit 4	0	0	0	9
	Total	**0**	**0**	**0**	**36**

Course No.	Course Name	L	T	P	C
Semester - 4					
EEOXXX	Open Elective 1	3	0	0	9
EEOXXX	Open Elective 2	3	0	0	9
EEC521	Thesis Unit 5	0	0	0	9
EEC522	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					
EED511	Power System Dynamics	3	0	0	9
EED512	Advanced Power System Protection	3	0	0	9
EED513	Power Quality	3	0	0	9
EED514	Power System Optimization	3	0	0	9
EED515	High Voltage Engineering	3	0	0	9
EED516	Power System Transients	3	0	0	9
EED501	Design of Power Converters	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

Total Theory papers

Departmental Core: 07

Departmental Elective: 03

Open Elective: 02

Total practical papers: 04

Thesis Units: 06

SEMESTER-I		
EEC501	**Power System Analysis**	**(3-0-0)**

Course philosophy :

This course deals with modern power system operational and control problems and solution techniques. Main objectives are:

- Estimation of system variables during fault.
- To understand the solution methods of economic dispatch and explain the automatic generation control of a single/multi-area power system.
- To provide the knowledge of hydrothermal scheduling, reactive power control.

Learning outcome:

The course covers most of the operational aspects of power system and would be helpful in developing basic research skills of the students. The course would also be of interest for practicing engineers.

Module 1: Introduction **[2L]**

Concept on structure of power system; Necessity of control of power system; Different control methods.

Module 2: Network modelling **[8L]**

Concept of primitive network; Formulation of [Y]-bus matrix using singular transformation; Formulation of [Y]-bus matrix with the inclusion of regulating transformer; tap-changing transformer; Formulation of [Z]-bus matrix; Fault calculations using Z-bus.

Module 3: Economic operation **[8L]**

Constraints in economic operation; Analytical approach for economic operation of thermal units: without line loss and with line loss; Transmission loss formula and economic operation; Algorithm and solution of optimal generation allocation.

Module 4: Hydro-thermal scheduling **[7L]**

Optimum scheduling of Hydro-thermal system; Aspects of Hydro-thermal system: Long term and short term scheduling.

Module 5: Automatic generation control (AGC) **[8L]**

Review of automatic load frequency control (ALFC); Responses of primary and secondary ALFC loops, ALFC of single area and multi area power systems; Static and dynamic performance;, AGC in a deregulated environment, Recent advances in AGC

Module 6: Reactive Power control **[6L]**

Application of automatic voltage regulator, OLTC Transformer, FACTS devices, synchronous condenser, static VAR compensators.

Total 39L

Recommended Books:

1. J.J. Grainger and W.D. Stevenson, "Power System Analysis", McGraw Hill Int. Student Ed.
2. A.J. Wood and B.F. Wollenburg, "Power Generation Operation and Control", Willey, Student Ed.

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 and
- current trend in machine control in industry

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

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** **[9 L]**

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** **[10 L]**

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]

Recommended Books:

[1] Generalized Theory of Electrical Machines: P.S. Bhimbra
[2] Generalized Theory of AC Machines: B. Adkins & R.G. Harley

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

<u>Course philosophy</u> :

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]

References:

1. Getting Started with MATLAB : RudraPratap
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.

Module 1: **[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

References:

[1] Modern control engineering – K Ogata

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

EEC505	HVDC transmission and FACTs	(3-0-0)

Course Philosophy: To educate the students about the recent methods of DC transmission, its applicability and possibility of HVAC transmission with HVDC. Also to familiarize the students about the use of flexible ac transmission devices in power transmission to cater the increasing load demand without expansion of transmission network.

Learning Outcome: To aware the students about the possibility of introduction of HVDC system into the current power transmission network. Also how power electronic based devices enhances the transmission capacity and efficiency without expansion of transmission network is another major issue to be apprised.

Module 1: **[8L]**

General aspects of DC Transmission and its application; types of DC link; MTDC transmission: series, parallel; comparative analysis of HVAC and HVDC system

Module 2: **[8L]**

Converter control characteristics; DC power flow control mechanism; Harmonic elimination; AC and DC filters

Module 3: **[8L]**

DC circuit breaker; transients and over-voltages in DC; insulators

Module 4: **[10L]**

Basic concepts of FACTS; different types of FACTS controllers and their needs in electric power transmission; Series Compensation – objective of series compensation, thyristor switch series capacitor (TCSC), static series synchronous compensator (SSSC); Shunt Compensation – objective of shunt compensation, Static-Var Compensator (SVC), Static compensator (STATCOM), performance analysis of SVC and STATCOM

Module 5: **[5L]**

Combined compensator: Unified power flow controller (UPFC), phase angle regulator (PAR)

Total 39L

References:

- Hingorani, Narain G., Laszlo Gyugyi. *Understanding FACTS: concepts and technology of flexible AC transmission systems*. Vol. 1. New York: IEEE press, 2000.
- Padiyar, K. R. *HVDC power transmission systems: technology and system interactions*. New Age International, 1990.

EEC506 Advanced Electrical Machines Laboratory

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.

EEC507 Advanced Power System Laboratory

1 To examine the characteristic of numerical overcurrent Relay

2 To study the Zonal Protection using Differential Relay.

3 To Study of Earth Fault Relay

4 To study of IDMT Directional Over Current Relay

5 To study power flow transfer (Active Power) through a transmission system

6 To study power flow transfer (Reactive Power) through a transmission system

7 To study of Percentage Differential Relay

8 To study Symmetrical and Unsymmetrical fault in transmission line using ELECTRICAL MACHINE TRAINER (EMT)

9 To study the Ferranti Effect of transmission line using ELECTRICAL MACHINE TRAINER (EMT)

10 To observe the flow of real and reactive power with bidirectional 3ϕ AC measurement using ELECTRICAL MACHINE TRAINER (EMT)

11. To study the characteristic of Doubly Fed Induction Generator

	SEMESTER II	
EED511	**Power System Dynamics**	**(3-0-0)**

Course Philosophy: The Syllabus is concerned with understanding, modelling, analyzing and mitigating power system dynamics and stability problems. Such problems constitute very important considerations in the planning, design and operation of modern power systems.

Learning Outcome:

- The student will have good grasp on model development for power generation system models both synchronous and asynchronous for power system dynamic studies and analysis.
- They would be able to interpret various parameters and and constants in various dynamic blocks in power system simulation software.
- They will have developed the skill to understand and validate generation system dynamic response through frequency domain analysis such as eigen-value analysis etc as their further effort.

Module 1: Basic concepts and definitions: **[2L]**

Rotor angle stability; Voltage stability and voltage collapse; Mid-term and long-term stability;

Module 2: Modelling of synchronous machines: **[8L]**

Review of basic equations of synchronous machine; The dq0 transformation; Equivalent circuits for direct and quadrature axes; Steady state analysis: Voltage, current and flux linkages relationships, Steady-state equivalent circuit, Procedure for computing steady state values; Electrical transient performance characteristics; Equations of motion: Swing equation, Its representation in system studies; Synchronous machine representation in stability study: approximated models for large-scale studies; Constant flux linkage models.

Module 3: Modelling of excitation systems: **[7L]**

Elements of an excitation system and their functions; Modelling of different components of DC excitation system, AC excitation systems, static excitation systems; Modelling of Power system stabilizer (PSS).

Module 4: Small signal stability: **[7L]**

Fundamental concept: State-space representation, stability of a dynamic system; Eigen properties of state matrix; Small signal stability of a single machine infinite bus system.

Module 5: Transient stability: **[7L]**

An elementary view on different methods; Transient stability of a large system; Direct method of analysis of transient stability.

Module 6: Voltage stability **[8L]**

Basic concept of voltage stability; Role of reactive power on voltage stability, P-V and Q-V profiles; Mechanism and causes of voltage collapse; Prevention of voltage collapse; Different voltage stability indicators; Reactive compensation methods; Methods of improving voltage stability; Sub-synchronous resonance.

Total [39L]

Recommended Books:

- Padyar, Power System Dynamics: Stability and Control, BPB Publications.
- PrabhaKundur, Power System Stability and Control, TATA McGraw-Hill Inc.

EED512	**Advanced Power System Protection**	**(3-0-0)**

Course Philosophy: To educate the students about the recent methods of DC transmission, its applicability and possibility of HVAC transmission with HVDC. Also to familiarize the students about the use of flexible ac transmission devices in power transmission to cater the increasing load demand without expansion of transmission network.

Learning Outcome: Students will be exposed to **MATLAB and PSCAD/EMTDC** software for writing the different digital relaying algorithms and verification of the developed algorithms on the generated data through PSCAD/EMTCD software.

Module 1: **[4L]**

Fundamentals of power system protection, relay terminology, principles of CB, CT, PT. selection and testing of CBs, transients in CBs. Evolution in protection systems.

Module 2: **[5L]**

Principles of relaying: Over current, Directional and Differential. Relay Coordination.

Module 3: **[3L]**

Protection challenges of distribution systems integrated with distributed generations. The impact of distributed generations on the conventional overcurrent relaying based distribution system protection scheme and possible newer solutions.

Module 4: **[4L]**

Transmission line protection using distance relays: Principles of simple impedance relay, Reactance relay, MHO relay. Impact of power swing on the performances of distance relays. Power swing blocking and out of step protection. Effect of line loadability on distance protection.

Module 5: **[3L]**

Transmission line fault location: principles and algorithms.

Module 6: **[4L]**

Problems and solutions for the protection of series compensated lines.

Module 7: **[10L]**

Basic elements of digital protection. Mathematical basis for numerical protective relaying algorithms: Sinusoidal wave based algorithms, Fourier algorithm, Least squares based methods, Differential equation based techniques, and Fundamentals of travelling wave based techniques.

Module 8: **[4L]**

Digital differential protection of transformers and transmission systems.

Module 9: [**2L**]

Introduction to Phasor Measurement Units (PMUs). Applications of wide area measurements for power system protection.

Total 39L

Recommended Books:

[1] A T Johns and S Kalman *'Digital Protection for Power Systems'*, IET, 1997.

[2] A G Phadke and J. Thorp *'Computer Relaying for Power Systems'*, Wiley, 2009.

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.

EED514	**Power System Optimization**	**(3-0-0)**

Course philosophy:

- Review the concepts of load flow in electrical power systems
- Study of the economic dispatch, optimal power flow and unit commitment problem of electrical transmission system and their solution techniques
- Empathize different optimization techniques to solve various power system optimization problems

Module 1: **Introduction** **[2L]**

Components of power system; Power system and computers; Real time planning and operation of power system

Module 2: **Load Flow Techniques** **[8L]**

Network model formulation; YBUS formulation; Load flow problem; Gauss-Seidel method; Newton-Raphson method; Fast decoupled load flow

Module 3: **Economic Dispatch and Optimal Power Flow** **[19L]**

Economic dispatch problem; Economic dispatch using Newton-Raphson method; Economic dispatch using exact loss formula; Economic dispatch based on penalty factors; Minimum emission dispatch; Optimal reactive power dispatch; Optimal power flow based on Newton method; Decoupled method for optimal power flow; Security constrained optimal power flow; Unit commitment and maintenance scheduling; Optimal hydrothermal scheduling

Module 4: **Optimization Techniques** **[10L]**

Introduction to optimization techniques; Multi-objective optimization – state-of-the-art; Evolutionary optimization; Genetic algorithm

Total 39L

Recommended Books:

1. Power System Optimization: D.P. Kothari and J.S. Dhillon
2. Electric Energy Systems Theory: O.I. Elgerd

EED515	**High Voltage Engineering**	**(3-0-0)**

Course Philosophy:

This syllabus has been designed with an eye on power engineering, and the topics considered are intricately related to power-engineering applications in general and dielectric engineering in particular. Apart from few basic modules, many of the topics are based on recent research publications and power utility requirements. For instance, numerical field computation and system modeling using COMSOL is a necessary knowledge and need of the day for any student who desires to be a power engineer. The syllabus is designed so that a student gets necessary mathematical foundation while gaining advanced knowledge in the field of High voltage engineering. All the topics have been selected in such a way that the reader gets an idea of how these theories are useful in real life.

Learning Outcome:

Module 1: **[8L]**

Numerical computation electric fields-

Graphical Method, Finite Difference Method (FDM), Integral method of field computation, fictitious point, line and ring charges, Finite element method of field computation, minimum field energy and basic potential equation at nodes, field computation in lossy dielectrics; conformal transformation for two-dimensional fields, elliptic cylinders bundle conductors, Mechanical forces in HV systems, Charge Simulation Method- introduction; modelling using COMSOL/ANSYS

Module 2: **[5L]**

Generation of High/Test Voltages and its measurement :

Alternating Voltages - Transformers in cascade, the series resonant circuit, Transient voltages - Impulse Generator, Tripping and synchronization with oscilloscope, Direct Voltages - Voltage Doublers and Cascade Circuits, Electrostatic Generators. Electrostatic Voltmeters, Sphere gaps, Uniform field gap, Ammeter in series with High Impedance, Potential Dividers; Peak voltmeters, instrument transformers; Voltage divider, HV Electrode.

Module 3: **[5L]**

Breakdown of insulation:

Different mechanism of breakdown of gaseous, liquid and solid dielectrics; HV equipment insulation design and stress controlling devices. Analysis of voltage distribution in transformer winding and bushings.

Module 4: **[4L]**

Lightning, switching and Power frequency over voltages:

The physical phenomenon of lightning, interaction between lightning and power system, switching surges and power frequency over voltages; Protection of equipment against over voltages, lightning arresters and surge suppressors, Ground wires, grounding practices, Insulation Coordination scheme for open air sub-station, Basic Impulse level; Fault current limiters.

Module 5: **[4L]**

Cables, insulators and bushings:

Voltage distribution and string efficiency in suspension insulators, Stress in cables, oil filled and gas filled cables, Cross linked cables, Capacitance grading, Inter-sheath grading,.

Module 6: **[6L]**

Partial Discharge Measurement and analysis:

Electrical method of PD measurement, PD inception and Extinction in closed cavity; Partial breakdown corona & EMI electromagnetic interference).

Module 7: **[7L]**

Insulation Response measurement and analysis:

Time and Frequency domain dielectric response; insulation condition determination using non-invasive electrical testing; Remaining Life Analysis-Life Estimation Based on Thermal Modeling ; Aging Acceleration and Hot-Spot Factor; Probabilistic Approach Towards Life Estimation; Application of Statistical analysis in HV ; Application of Optimization techniques in Contour optimization

Total 39L

Recommended Books:

[1] Farouk A.M. Rizk, Gian N Trinh "High Voltage Engineering", CRC Press

[2] S. Chakravorti, D Dey, B. Chatterjee "Recent Trends in the Condition Monitoring of Transformers", CRC Press

EED516	Power System Transients	(3-0-0)

Course Philosophy: This syllabus has been designed with an eye on energy industry, and the topics considered are intricately related to power system network operations. Apart from few basic modules, many of the topics introduced are crucial for power system network operation. The syllabus is designed so that a student gets necessary mathematical foundation while gaining advanced knowledge related to power systems transient.

Learning Outcome: Students will gain knowledge about system modelling using EMTP/PSCAD, lightning performance of towers, back-flashover, influence of TFR. These factors play crucial role in the planning, design, maintenance and operation of modern power system network.

Module 1: **[6L]**

Internal and external causes of over voltages-

Lightning strokes – Mathematical model to represent lightning, Travelling waves in transmission lines – Circuits with distributed constants – Wave equations – Reflection and refraction of travelling waves – Travelling waves at different line terminations, Travelling wave method – Beweley's Lattice diagram – analysis in time and frequency domain.

Module 2: **[8L]**

Travelling wave attenuation and distortion, transients due to faults, electromagnetic induction, magnetic flux, and currents, transient electromagnetic phenomena, lightning induced transients, computation of lightning events, lightning protection using shielding and surge arresters, transient voltages and grounding practices, lightning performance of transmission towers, Influence of surge impedance, Tower Footing Resistance in lightning performance of double circuit lines, back-flashover.

Module 3: **[8L]**

Sources of Transients and their effect on Power System network:

Switching transients –double frequency transients – abnormal switching transients – Transients in switching a three phase reactor- three phase capacitor. Voltage and current chopping, Line energization, and de-energization transients; voltage distribution in transformer winding – voltage surges in transformers, generators and motors, Transient parameter values for transformers, reactors, generators and transmission lines. Basic ideas about protection –surge diverters-surge absorbers-protection of lines and sub-stations.

Module 4: **[5L]**

Insulation coordination:

Basic Insulation Level (BIL), Critical Flashover Voltage (CVO), Over voltage protective devices – shielding wires, Lightning arresters, rods gaps and surge diverters, principles of insulation coordination-recent advancements in insulation coordination – design of EHV system.

Module 5: **[6L]**

Representation of transient wave shapes, modelling power apparatus for transient analysis, capacitor switching, reactor switching, magnetizing inrush and ferro-resonance, transmission lines, the wave equation, and line terminations, Generation, properties and application of high AC and DC-impulse voltages, currents.

Module 6: **[6L]**

Modelling of Transients and its effect on power system network:

EMTP, PSCAD/EMTDC software, Simulation of surge diverters in transient analysis; Influence of pole-opening and pole-reclosing; Fourier integral and Z-transform methods in power systems transients;

Bergeron methods of analysis and the use of the EMTP, PSCAD/EMTDC package; numerical simulation of electrical transients, international standards.

Total **39L**

Recommended Books:

1. A. Greenwood, “Electrical Transients in Power Systems”, Wiley.
2. J. A. Martinez-Velasco, “Power System Transients: Parameter Determination”, CRC Press.

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)

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.

EEC513 Advanced power System Simulation Laboratory

1 Y (admittance) bus matrix formulation
2 Newton Raphson Load flow analysis
3 Determination of Active Power Loss for power systems test networks
4 Generation scheduling and fuel cost calculation
5 Economic load dispatch with Lagrange multiplier (without constraints and system loss)
6 Economic load dispatch with Lagrange multiplier (with constraints and system loss)
7 Economic load dispatch with soft computing techniques (with constraints and system loss)
8 Modelling of FACTS devices using SIMULINK
9 Reactive power dispatch problem modelling
10 Reactive power planning problem modelling

EEC514 Advanced Power System Protection Laboratory

1. To determine the operating characteristics of an Induction type IDMT Overcurrent Relay.

2. To determine the operating characteristics of a Numerical type IDMT Overcurrent Relay.
3. To determine the operating characteristics of a Numerical type Under Voltage/Over Voltage Relay.
4. To determine the operating characteristics of an electromechanical IDMT Directional-Overcurrent Relay.
5. Fault study and distribution feeder protection using numerical Overcurrent Relay.
6. Fault study and protection of parallel distribution feeders.
7. Fault study and transmission line protection using Distance Relay.
8. Faulty phase identification using synchronized measurements at both ends of the transmission line.
9. Study and protection of Transformers using Percentage Differential relay.
10. Study and protection of three-phase ac motors.

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

<u>Course philosophy</u> :

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

<u>Learning outcome:</u>

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

EEO512	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

EEO513	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.