Course Name	**:**	**Design of Experiments and Research Methodologies**
Course Code	**:**	**EER1001**
Credits	**:**	**3**
LTP	**:**	**3-0-0**

Course Objectives:

At the end of this course, the students should be able to
(i) Develop an understanding of how to identify research topics, formulate research questions / hypotheses, select an appropriate research and, where applicable, experimental design
(ii) Effectively develop a research proposal for either a master's thesis, research project, or designedexperiment.

Total No. of Lecture 28

Total No. of Lab hrs. 28

Lecture Wise Breakup		**Number of Lecture**
1.	**Introduction**: Types of Research and Their Purposes, Locating, Analysing, stating and evaluating research problem, need for literaturereview, steps in conducting literature review, Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis, research questions and hypothesis, types of hypothesis, evaluation of hypothesis.	4
2.	**Research Design and Sampling Design:** Concept of research design, features of a good research design, concept of population and sample, characteristics of sample design, types of sampling techniques	5
3.	**Methods of data collection and measurement:** Primary data and Secondary data, data collection techniques: observation, interview, questionnaires, schedules, case-study, levels of measurement, problems inmeasurement in research – validity, reliability.	6
4.	**Statistical Methods of Analysis:** Descriptive statistics: mean, median, mode, range, mean deviation and standard deviation, regression and correlation analysis, inferential statistics: t-tests, Chi-square tests. Correlation (rank difference and product moment), Analysis of variance(ANOVA) (one way)	8
5.	**Procedure for writing a research report and manuscript:** Types of research reports, steps of writing a report, layout of report, layout of research paper, ethical issues related to publishing, Plagiarism and Self-Plagiarism.	5

Course Outcomes: By the end of this course, the students will be able to

CO1	Develop an understanding of how to identify research topics, formulate research questions and corresponding hypotheses, select an appropriate research and whereapplicable, experimental design
CO2	Perform required statistical analyses for any univariate application in a business / industrial setting, regardless of data form, and will be familiar with major indices for measuring correlation and association.
CO3	Understand and review the underlying assumptions related to each statistical test and itsinterpretation

Suggested Books:

Sr. No.	**Name of Book/Authors/Publisher**	**Year of Publication/ Reprint**
1.	Probability and Statistics for Engineers and scientists by Anthony J. Hayter, Cencage Learning, 4th Edition	2016
2.	Probability and Statistics for Engineers and scientists by Walpole, Myers, Myers and Ye, 8th ed Pearson Education	2007
3.	Research Methodology - Methods and Techniques, C. K. Kothari, NewAge International, 2nd Edition	2004
4.	English for writing research papers by Adrian Wallwork, 2nd Edition.Springer	2016
5.	Statistics: Concepts and Controversies by David S. Moore, William I.Notz, W. H. Freeman	2016

List of Experiments		
Sr. No	**Experiment Name**	**No of Turns**
1.	Select a problem from your area of interest, identifying the type of research problem it is and perform the SWOT analysis of the existing literature.	2
2.	Generate research questions and hypotheses for a problem from your area of interest.	2
3.	Identify the population and sample for the study (highlighting the technique used for sample selection) for a problem from your area of interest	2
4.	Design a questionnaire for the problem of interest.	2
5.	Utilizing software such as Statistical Package for the Social Sciences (SPSS), Mini Tab, etc. for the statistical analysis of the results obtained for the desired questionnaire.	3
6.	Preparing a research paper for the problem of interest	3

Program Core-I

Course Name	**:**	**Advance Power System Analysis**
Course Code	**:**	**EER1101**
Credits	**:**	**3**
L T P	**:**	**2 0 2**
Course Objectives:		
At the end of this course, the student should be able to acquire knowledge of 1. The modelling and analysis of three phase power system in steady state, 2. System security by contingency analysis, 3. State estimation techniques in power system.		

Total No. of Lectures-28

	Lecture wise breakup	Number of Lectures
1.	**Power Flow Studies:** Review of power flow studies, formation of Y & Z bus with mutual impedances, Comparison of various methods of load flow solution, AC-DC load flow.	04
2.	**Three phase networks:** Three phase network elements, three phase balanced network, Transformation matrices. Three phase unbalanced network elements. Algorithm for formation of three phase bus impedance matrix. Modification of three-phase bus impedance matrix for changes in the network, 3-φ load flow analysis.	07
3.	**Network fault and contingency analysis:** Fault computation using Z-bus. Short-circuit calculations for three phase networks using Z bus. Contingency analysis for Power systems.	07
4.	**State estimation from line measurements:** The line power flow state estimator. State estimation and noisy measurements. Monitoring the power system Determination of variance χZ2 – to normalize measurements, Improving state estimates by adding measurements.	06
5.	**Probabilistic power flow:** Voltage issues in power system with renewable power integration, Probabilistic steady state analysis of power system integrated with different renewable resources**.**	04

Course Outcomes: By the end of this course, the student will be able to:	
CO1	The students shall be able to model the power system
CO2	The students shall be able to analyze the power system in the steady state
CO3	The students shall be able to apply the contingency analysis under different fault conditions
CO4	The state estimation from line measurements can be done by the students
CO5	The students shall be able to analyze the power system in the steady state integrated with renewable resources

Text Books:	
1.	Glonn N. Stagg and ahmed H. El-Abiad, “Computer Methods in Power System Analysis” McGraw Hill, International Edition 1988.
2.	Grangier & Stevenson “Power System Analysis”, McGraw Hill International Students Edition-1994.

Reference Books:	
1.	George L.Kusic, “Computer-aided Power system Analysis”, Prentice Hall, 1986.
2.	J.Arrillaga, C.P. Amold and B.J. Harker, “Computer Modelling of Electrical Power Systems, John willey& Sons, 1983.
3.	O.I. Elgard,Electric Energy Systems– An Introduction, TataMcgraw Hill, 1971.
4.	M.A. Pai, Computer Techniques in Power System Analysis, Tata McGraw Hill, 1979.
5.	P.M. Anderson, Analysis of Faulted Power Systems, IEEE Press Book.
6.	L P Singh, Advance Power System Analysis and Dynamics, New Age international Publisher, 2008
7.	P. Venkatesh, B. V. Manikandan, S. Charles Raja, Electrical Power Systems: Analysis, Security And Deregulation, PHI 2012

List of experiments to be performed: *(Software ETAP/ PSCAD / MATLAB / MATPOWER/power world will be used)*		
S. No.	**Name of Experiment**	**Number of Turns**
1.	Load flow studies	1
2.	Short circuit studies	1
3.	Optimal power flow	1
4.	Optimal power flow with renewable sources	1
5.	Economic Load Dispatch with thermal power plants.	2
6.	Economic Load Dispatch with Hydro thermal power plants	2
7.	Simulation of protection ckts.	2
8.	Simulation of single -area and Two -area Systems.	2
9.	Unit commitment.	2

Course Name	**:**	**Modern Control Systems**
Course Code	**:**	**EER1121**
Credits	**:**	**03**
L T P	**:**	**2-0-2**

Course Objectives: At the end of the course, the student should able to:

1. Learn the modelling concepts of system using state space.
2. Understand the application of optimal control techniques.
3. Learn the fundamentals of digital control systems and non-linear systems.

Total No. of Lectures: 28

Lecture Wise Breakup		Number of Lectures
1.	**Introduction** Control systems design requirements, classical versus modern approaches of design.	02
2.	**State Space Representation** Concepts related to state space, state space representation, state transition matrix, solution of linear time invariant and linear time varying state equations, canonical forms.	03
3.	**Control System Design in State Space** Controllability, pole placement design using full state feedback-regulator and tracking systems, observers, observability and compensators, full order and reduced order observers.	06
4.	**Linear Optimal Control** Optimal control problem, infinite time linear optimal regulator design, optimal control of tracking systems (Riccati equation based designs).	06
5.	**Digital Control Systems** Basic concepts, z-transform, stability, performance, state space modeling and solution of linear digital equations, design using pole placement, regulators and observers and compensators, linear optimal control of digital systems, digital Kalman filters and optimal design of compensators.	07
6.	**Nonlinear Control Systems** Sources of nonlinearities and characteristics of nonlinear systems, describing function method, phase plane analysis, Lyapunov stability theory.	04

Lab Work:

S.NO.	Lab Contents	Lab Turns
1.	State space modeling of continuous time system and study of stability and state and output responses	**01**
2.	Pole placement design using state feedback for regulator and tracking systems	**01**
3.	Full and reduced order observer design	**02**
4.	State space modeling of discrete time system and study of responses	**02**
5.	Pole placement design for regulator and tracking discrete time systems	**02**
6.	Observer design for discrete time systems	**02**
7.	Describing function analysis of nonlinear systems	**02**
8.	Phase plane analysis of nonlinear systems	**02**

Course Outcomes: By the end of this course, the student will be able to:

CO1	Apply the modeling concepts of system using state space.
CO2	Design different types of observers for the linear systems.
CO3	Design optimal control techniques for linear systems.
CO4	Design and analyze the digital control systems.
CO5	Implement and analyze the stability of non-linear systems.

Text Books:		
Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	AshishTewari, Modern Control Design with MATLAB and SIMULINK, John Wiley and Sons Ltd	2002
2.	K. Ogata, Modern Control Engineering, PHI.	2014
3.	M. Gopal, Modern Control System Theory, New Age International (P) Ltd.	2005

Reference Books:		
Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	M. Gopal, Digital Control and State Variable Methods, TMH.	2003
2.	William L. Brogan, Modern Control Theory, Pearson Education India.	2011

Course Name	**:**	**Solid State Control of Drives**
Course Code	**:**	**EER1111**
Credits	**:**	**3**
LTP	**:**	**2-0-2**

Course Objectives:

At the end of this course, the students should be able to
1. Realize the concepts of solid state devices
2. Acquire the basics of application of solid state devices for the control of conventional electric drives.

Total No. of Lecture - 28

Lecture Wise Breakup		**Number of Lecture**
1.	**DC Motor Drives** Introduction to Electrical Drives, Dynamics of Electrical Drives. Review of Torque-Speed Characteristics of DC Motors (Shunt and Series) including Motoring and Braking. Converter (Half Controlled Converter, Full Controlled Converter, Dual Converters). Control of DC Motor Drives. Torque Speed Characteristics of Converter-fed DC Drives. Chopper Controlled DC Drives (Single and Multi-quadrant Converters), Motoring and Braking operations.	10
2.	**Induction Motor Drives** Induction Motor Drives – Equivalent circuits; Torque-speed characteristics; Operation of Induction Motor with Unbalanced Source Voltages; Analysis of Induction Motor from Non-Sinusoidal Voltage Supply; Starting and Braking of Induction Motor. Stator Voltage Control of Induction Motor; Variable Voltage/Current; Variable Frequency Control of Induction Motor Fed from VSI and CSI; Control of Slip-ring Induction Motor	10
3.	**Synchronous Motor Drives** Synchronous Motor Characteristics (Cylindrical and Salient Pole); CSI-fed Synchronous Motor Drive; Constructional features of permanent magnet machines, Permanent Magnet Synchronous Motor Drives, Brushless DC Motor Drives.	8

Course Outcomes: By the end of this course, the students will be able to

CO1	Realize the basic dynamics of DC Motor, Induction Motor and Synchronous Motor.
CO2	Acquire knowledge of operation of solid state convertors
CO3	Realize the application of solid state convertors for the control of DC Motor, Induction Motor and Synchronous Motor Drives.

Suggested Books:

Sr. No.	**Name of Book/Authors/Publisher**	**Year of Publication/ Reprint**
1.	G K Dubey, Fundamentals of Electric Drives, ISBN 9788173190414	2002
2.	G K Dubey, Power Semiconductor Controlled Drives, Prentice Hall	1989
3.	W Shepherd and L N Hulley, Power Electronics and Motor Control, Cambridge University Press	1995

List of Experiments

Sr. No	**Experiment Name**	**No of Turns**
1.	To obtain the closed loop speed control of DC machine using 3-phase full wave fully controlled thyristorized converter.	2
2.	To obtain the speed control of DC machine using first quadrant chopper.	2
3.	To obtain four quadrant operation of DC motor using IGBT based DC chopper.	2
4.	To simulate the speed control of DC machine using four quadrant chopper and evaluate the performance using different chopping frequencies.	2
5.	To obtain speed control performance of induction motor using AC voltage regulator.	2
6.	To obtain speed control performance of induction motor using V/F control.	2
7.	To obtain speed control performance of synchronous motor using CSI.	2

Program Core-II

Course Name	:	**Advance Power System Protection**
Course Code	:	**EER1102**
Credits	:	**3**
L T P	:	**3-0-0**

Course Objectives:
The students are expected to understand the fundamentals of 1. Modern power system protection using PLC, SCADA, microprocessors based protection systems 2. Protection of wind and solar plants 3. Protection of transmission line

Total No. of Lectures-42

Lecture wise breakup		**Number of Lectures**
1.	The need for electrical protection. Overview of electrical faults. The principles behind the protection of the power system and its components. The relay/circuit-breaker combination. Instrument transformers.	03
2.	Differential protection Voltage regulation protection. Frequency regulation protection. Distance protection. Negative sequence protection.	03
3.	Introduction to Computer Relaying. Remote substation access and local intelligence. PLCs. SCADA Systems. Microprocessor and PLC based protection schemes.	07
4.	Integrated approach to power system protection using the existing electromechanical relays, the static electronic relays, and the microprocessor based digital relays.	07
5	Knowledge of transmission line relaying and the algorithms used in computer relaying.	06
6.	Adaptive relaying, real-time feedback system for increased security. Study of the response of protection systems to transient phenomena. EHV System Protection**.**	07
7.	Protection System failures. Case studies of Blackouts: Causes and Countermeasures	06
8.	Protection of Wind and Solar Plants.	03

Course Outcomes: By the end of this course, the student will be able to:	
CO1	The fundamentals of modern power system protection
CO2	Power system protection using PLC, SCADA, microprocessors-based protection systems
CO3	Different protection schemes and transmission line protection
CO4	Causes of protection failures
CO5	Protection schemes of wind and solar plants.

Text Books:	
1.	T S Madhav Rao , Power System Protection, Static Relays with Microprocessor applications, Tata McGraw Hill, 1989
2.	Badri Ram, D. N. Vishwakarma, Power System Protection and Switchgear, Tata McGraw-Hill Education, 2011

Reference Books:	
1.	A. Allan T Johns, Salman K. Salman, Digital Protection for Power Systems, 1995
2.	Arun G. Phadke, James S. Thorp, Computer Relaying for Power Systems, John Wiley & Sons 2009
3.	Stanley H. Horowitz and Arun G. Phadke, Power System Relaying, Third Edition, John Wiley.2014
4.	L. P. Singh., Digital Protection: Protective Relaying from Electromechanical to Microprocessor, New Age International, 1994

Course Name	**:**	**Robust Control**
Course Code	**:**	**EER1122**
Credits	**:**	**03**
L T P	**:**	**3-0-0**

Course Objectives:

At the end of the course, the student should be able to:
1. Learn and practice the fundamentals of robust control system
2. Determine concepts such as H_2 and H∞ spaces, structure stability and performance
3. Grasp the different uncertainties, linear fractional transformations, singular value synthesis and controller parameterization technique.

Total No. of Lectures: 42

Lecture Wise Breakup		**Number of Lectures**
1.	**Introduction** Vector spaces, Linear subspaces, invariant subspaces, vector norms and matrix norms, singular value decomposition, semidefinite matrices, description of linear systems, operations on systems, state space realizations for transfer matrices, multivariable poles and zeros.	04
2.	**H_2 and H∞ Spaces** Hilbert spaces, H_2 and H∞ spaces, computing of L_2 and H_2 norms, computing of L∞ and H∞ norms.	05
3.	**Internal Stability** Feedback Structure, internal stability, coprime factorization over RH∞.	03
4.	**Performance Specifications** Feedback properties. Weighted H_2 and H∞ performances, selection of weighting functions.	03
5.	**Uncertainty and Robustness** Model uncertainty, small gain theorem, stability under unstructured uncertainties, robust performance.	03
6.	**Linear Fractional Transformations** Linear Fractional Transformations, block diagrams, basic principles, Redheffer star products.	03
7.	**Structured Singular Values Synthesis** General framework for system robustness, SSV, structured robust stability and performance, SSV synthesis.	03
8.	**Controller parametrization** Existence of stabilizing controller, controller parametrization, coprime factorization approach.	03
9.	**Algebraic Riccati equation** Stabilizing solution and Riccati operator, inner functions.	03
10.	**H_2 Optimal Control** Standard and extended LQR problems, guaranteed stability margins of LQR, standard H_2 problem, stability margins of H_2 controllers, LQG/LTR.	06
11.	**H∞ Control** Various problem formulations, general H∞ solutions, H_2 and H∞ integral control, H∞ filtering, H∞ controller reductions, Case studies of controller designs.	06

Course Outcomes: By the end of this course, the student will be able to:	
CO1	Apply the fundamentals of robust control systems and their concepts such as H_2 and H∞ spaces.
CO2	Analyze the structure stability and performance with uncertainties.
CO3	Apply the concepts of linear fractional transformations, singular value synthesis and controller parameterization for practice and practical problems.
CO4	Apply and analyze the implementation of H_2 control problems.
CO5	Apply and analyze the implementation of H_∞ control problems.

Text Books:		
Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	Kemin Zhou and J.C. Doyle, Essentials of Robust Control, Prentice Hall.	1998
2	JC Doyle, B Francis, and A. Tannenbaum, Feedback Control Theory.	1992

Reference Books:		
Sr. No	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	Ricardo S Sanchez-Pena & Mario Sznaier, Robust Systems Theory and Applications, John Wiley & Sons.	1998
2	J.M.Maciejowski, Multivariable Feedback Design, Addison-Wesley Publishing Company.	1989

Course Name	**:**	**Analysis and Design of Power Electronic Converters**
Course Code	**:**	**EER1112**
Credits	**:**	**3**
LTP	**:**	**3-0-0**
Course Objectives:		
At the end of this course, the students will be able to 1. Analyze different types of power convertors 2. Design magnetic circuit of basic power convertors 3. Design control loop of basic power convertors		

Total No. of Lecture - 42

Lecture Wise Breakup		**Number of Lecture**
1.	**Introduction to Power Electronic Devices and Power Processing** Review of power switching devices, basic structure, switching and I-V characteristics. I Calculation of switching losses in various power converters. Introduction to Power Processing, Principles of Steady State Converter Analysis: Inductor volt-second balance, Capacitor Charge Balance and Small Ripple Approximation.	5
2.	**Switch Realization in Power Convertors** SPST realization of different types of power converters and transformation of SPST realization to switch realization. Realization of single quadrant switches, current bidirectional two quadrant switches, voltage bidirectional two quadrant switches, four quadrant switches.	11
3.	**Convertor Circuits: Analysis** Steady State Analysis of buck, boost, buck-boost, CUK and SEPIC convertors. CCM/DCM modes, effect of inductor DCR, effect of capacitor ESR, DC voltage transfer function. Isolated convertors: Full and half bridge, forward, push-pull, flyback. Isolated versions of SEPIC and CUK convertor.	14
4.	**Convertor Circuits: Design** Design of magnetics for power convertors: choice of core, inductor design with area product method, kg method. Small signal modelling of power converters. Introduction to controller design for power convertors in frequency domain, loop shaping, voltage mode control.	12

Course Outcomes: By the end of this course, the students will be able to	
CO1	Realize power processing of power electronic devices
CO2	Realize switching operation of basic power electronic convertors
CO3	Model and analyze basic power electronic convertors
CO4	Design the magnetics of power electronic convertors
CO5	Design the control loop of power electronic convertors

Suggested Books:		
Sr. No.	**Name of Book/Authors/Publisher**	**Year of Publication/ Reprint**
1.	Robert W. Erickson & Dragan Maksimovic, Fundamentals of Power Electronics, second edition, springer. ISBN 9788181283634	2014

Program Core-III

Course Name	**:**	**Power System Operation and Control**
Course Code	**:**	**EER1103**
Credits	**:**	**3**
L T P	**:**	**3-0-0**
Course Objectives:		
The students undergoing this course are expected to 1. Learn analytical methods and numerical techniques for solving operation-related problems of power system operation, e.g security, economic dispatch, unit commitment frequency control 2. Learn fundamentals of energy management systems and Control techniques. 3. Model and solve optimal power flow problem under different conditions.		

Total No. of Lectures-42

	Lecture wise breakup	Number of Lectures
1.	**Power Systems Operational Security and Dispatch** Review of security concept and state of operation, generation dispatch; dynamic security, economic load dispatch.	05
2.	**Frequency Control and AGC** Review of theory of frequency dynamics. Multi-area frequency dynamics, Load-frequency and tie-line power flow control. Theory of Automatic Generation control, AGC implementation methods.	07
3.	**Interconnected Systems Operation** Need of system interconnection. Operating policies, Economic interchange, Optimal multi-area Operation.	07
4.	**Unit Commitment** Priority lists, Integer Programming, Dynamic Programming, Lagrangian Relaxation, unit commitment with renewable energy (single & multi-objective)	07
5.	**Energy Management Systems and Real-Time Control** Energy management systems, Software & hardware resources and configurations. Data management. Communications and distributed computing. Expert systems for contingency and security evaluation, event analysis, system restoration and reactive control. Short range load forecasting.	09
6.	**Optimal Power Flow** Introduction to Optimal Power Flow Techniques and Optimal Power Flow with conventional sources, Optimum Scheduling and Dispatch Of Power Systems with Renewable Generations, Reactive Power Management in Power Systems Integrated with Renewable generation, Role of Stochastic Optimization for Power System Operation and Decision Making	07

Course Outcomes: By the end of this course, the student will be able to:	
CO1	Apply the concepts of power systems operation, security, dispatch and unit commitment
CO2	Understand the need and operating polices for Interconnected Systems Operation
CO3	Do the frequency control and AGC in single area and Interconnected Systems Operation
CO4	Understand energy management Systems in power system
CO5	Model optimal power flow with conventional and renewable resources.

Text Books:	
1.	Wood and Wollenberg "Power Generation Operation and Control", John Wiley, 1984.

Reference Books:	
1.	OI Elgerd "Electric Energy Systems, Theory", McGraw Hill, 1983
2.	Mahalanabis et al., "Computer-aided power system analysis" Tata McGraw, 1988.
3.	Anderson &Fouand "Power system control and stability" Lowa State University Press, 1977.
4.	"Fundamentals of supervisory systems" IEEE Tutorial Course Text, 91EH0337-6PWR, 1991.

Course Name	**:**	**Linear Optimal Control**
Course Code	**:**	**EER1123**
Credits	**:**	**03**
L T P	**:**	**3-0-0**

Course Objectives:

At the end of the course, the student should be able to:
1. Learn the concepts of state-space fundamentals
2. Learn to design linear state feedback control laws, observer and observer based controllers.
3. Grasp the concepts of optimal control: general mathematical procedures, optimal feedback control, stochastic optimal linear estimation and control.

Total No. of Lectures: 42

Lecture Wise Breakup		**Number of Lectures**
1.	**State-space Fundamentals** State-space representation & solution of state equation, state transition matrix, realizations, transformations, stability concepts , Controllability & observability.	05
2.	**Design of linear state feedback control laws** State feedback control laws, shaping of dynamic response, closed loop eigenvalue placement via state feedback, stabilizability, steady state tracking.	05
3.	**Observer and observer based controllers** Observers, detectability, reduced order observers, observer based compensators and separation property, steady state tracking with observer based compensators.	06
4.	**Optimal Control: General mathematical procedures** Formulation of optimal control problem, calculus of variation, minimum principle, dynamic programming.	10
5.	**Optimal Feedback Control** Linear state regulator, continuous time linear state regulator, use of linear regulator to solve other linear optimal control problems, Suboptimal Linear regulators, Minimum time control of LTI systems.	10
6.	**Stochastic optimal Linear Estimation and Control** Stochastic processes and linear systems, optimal estimation for linear continuous & discrete time systems, stochastic optimal linear regulator.	06

Course Outcomes: By the end of this course, the student will be able to:	
CO1	Apply the concepts of state-space fundamentals.
CO2	Design various linear state feedback control laws.
CO3	Design the different observers and observer based controllers.
CO4	Implement the optimal control: general mathematical procedures, optimal feedback control.
CO5	Implement the stochastic optimal linear estimation and control.

Text Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	Robert L Williams II & Douglas A. Lawrence, Linear state-space control systems, John Wiley & Sons, Inc.	2007
2.	K. Ogata, Modern Control Engineering, PHI.	2010
3.	M. Gopal, Modern Control System Theory, New Age International (P) Ltd.	1993
4.	K.J. Astrom, Introduction Stochastic Control Theory, Academic Press.	2012

Reference Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	RE Bellman, Dynamic Programming, Princeton University Press	1957
2.	B.D.O Anderson and JB Moore, Linear Optimal Control, Prentice Hall	1972

Course Name	**:**	**Dynamical Modelling of Electrical Machines**
Course Code	**:**	**EER1113**
Credits	**:**	**3**
LTP	**:**	**3-0-0**

Course Objectives:

At the end of this course, the students should be able to
1. Realize the concept of linear transformation in electrical machines
2. Model and analyze dynamics of electrical machines on a common framework of generalized theory of electrical machines.

Total No. of Lecture - 42

Lecture Wise Breakup		**Number of Lecture**
1.	**General Theory of Electrical Machines and Transformations** Kron's Primitive Machine Model (Two Axis Model), statically induced EMF, Rotational or Dynamically Induced EMF, Generalized Torque Expression of Kron's Primitive machine. Modelling of Separately Excited, Series and Shunt DC Machine using Kron's Primitive Machine Model. Linear transformation in Machines: Concept of power invariance, assumption for linear transformation. Linear transformation – Phase Transformation – Transformation to a Reference frame Transformation from displaced brushes, Phase transformation from three phases(a,b,c) to rotating two phases(α,β,o), transformation from rotating two axis (α,β,o) to stationary two axes (d,q,o). Concept of connection matrix.	10
2.	**Modeling of D.C. Machines** Voltage and Current relationship – Torque equation, Mathematical model of separately excited DC motor and DC Series motor in state variable from – Transfer function of the motor – Numerical problems, Mathematical model of D.C. shunt motor and D.C. Compound motor instate variable from – Transfer function of the motor – Numerical Problems.	10
3.	**Modeling of Induction Motor** Circuit model of a 3 phase Induction motor, – Two axis models for Induction motor. Voltage and Current Equations in stator reference frame – Equation in Rotor reference frame – Equations in a synchronously rotating frame – Torque equation – Equations in state-space from. Induction motor dynamics during starting and braking.	11
4.	**Modeling of Synchronous Machines** General synchronous machine equations, Circuit model of a 3 phase Synchronous machine, two axis representation of Synchronous Machine. Voltage and current Equations in State–space variable from, power-angle characteristics during steady state and transient state. The concept of time-constants, significance of SCR, synchronous machine dynamics (electro-mechanical transients).	11

Course Outcomes: By the end of this course, the students will be able to

CO1	Realize the basic concepts of machine modelling
CO2	Realize the concept of linear transformation in electrical machines
CO3	Apply the basic concepts of machine modeling and analysis using the generalized theory of Electrical Machines.
CO4	Apply the generalized theory of electrical machines for dc machines, induction motor, synchronous machine and analyze under different operating conditions for research in the area of electric drives.

Suggested Books:

Sr. No.	**Name of Book/Authors/Publisher**	**Year of Publication/ Reprint**
1.	Electric Motor Drives: Modeling Analysis & Control by R. Krishnan, Prentice Hall. ISBN 9780130910141	2001
2.	The General Theory of Alternating Current Machines: Application to Practical Problems by Bernard Adkin, Ronald G. Harley, Published by Chapman and Hall Ltd. London,	1975

3.	Analysis of Electric Machinery and Drive systems – Paul C.Krause, Oleg wasynezuk, Scott D. Sudhoff. ISBN 9780471143260	2002

Program Core-IV

Course Name	**:**	**Power System Dynamics**
Course Code	**:**	**EER1104**
Credits	**:**	**3**
L T P	**:**	**2-0-2**
Course Objectives:		
In this course the students are expected to 1. Learn the basic concepts of power system behaviour of linear and non-linear system stability. 2. Learn the methods of system analysis in steady state and transient state operating conditions. 3. To learn FACTS devices for improvement of power system stability.		

Total No. of Lectures-28

	Lecture wise breakup	**Number of Lectures**
1.	Brief survey of Power System Analysis and operation, Active power & Reactive power. System response to power impacts, power plant response, AGC. Basic Concepts of dynamical systems and their stability.	05
2.	Modelling of power system: modelling of generators, transmission lines, excitation, prime mover controllers, and loads under steady-state, transient state (due to large and small disturbances).	06
3.	Analysis of single machine and multi-machine systems. Small signal angle instability (low frequency oscillations): damping and synchronizing torque analysis, eigenvalue analysis.	06
4.	Review of transient stability, numerical integration methods. Transient stability analysis of single machine connected to infinite bus. Transient stability analysis of Multimachine system. Evaluation of transient stability by direct method.	06
5.	Power system stabilizers, supplementary modulation control of FACTS devices. Transient and small signal angle instability counter-measures. Series capacitors, shunt capacitors and Shunt Reactors, SVS, Comparison between Series and Shunt Compensation Synchronous condensers.	05

Course Outcomes: By the end of this course, the student will be able to:	
CO1	Explain the basic concepts of power system behaviour of linear and non-linear system stability
CO2	Model the power system components.
CO3	Apply the methods of system analysis in steady state and transient state operating conditions
CO4	Investigate FACTS devices for improvement of power system stability.

Text Books:	
1.	P. Kundur , Power System Stability and Control' – 1994
2.	P. Sauer & M. A. Pai , Power System Dynamics & Stability' -2006

Reference Books	
1.	K.R. Padiyar, Power System Dynamics Stability and Control'– B.S. Publisher (2004).
2.	L. P. Singh, Advanced Power System Analysis and Dynamics, New Age International Publishers, New Delhi, 6th Edition, 2012.
3.	V.A. Venikov, Transient Phenomena in power system, Mir Publications (2014).
4.	A.A. Fouad and P.M. Anderson, Power system stability and control, Iowa University Press, Ames, Iowa, 1977.
5.	E.W. Kimbark, Power system Stability, Vol. I and III, John Wiley and Sons, Inc., New York, 1948.
6.	Narain Hingorani, et al, Understanding FACTS: Concepts And Technology Of Flexible AC Transmission Systems," IEEE Press Standard Publisher Distributors, Delhi-110006,1st Indian Edition,2001.
7.	Pertinent IEEE papers.

Sr. No	Experiment	No. of Lab. turns
1.	To study transient stability of single machine connected to infinite bus by point method.	2
2.	Short circuit analysis of standard test systems using Power World Simulator/MATLAB Packages.	2
3.	To Study Power System Dynamics for Load-Frequency Control of single area.	2
4.	To Study Power System Dynamics for Load-Frequency Control of multi-area and effect on tie-line control.	2
5.	To incorporate various controllers for improvement of Power System Dynamics.	2
6.	To simulate SMIB using Phillips-Heffron Model and study Small Signal Stability.	2
7.	To Simulate FACTS devices and implement into SIMB/Multi-machine system	2

Course Name	**:**	**Discrete Time Control Systems**
Course Code	**:**	**EER1124**
Credits	**:**	**03**
L T P	**:**	**2-0-2**

Course Objectives:

At the end of the course, the student should be able to:
1. Learn the concepts of signal processing and digital control, z-transformation,
2. Learn to design digital control algorithms.
3. Grasp the state-variable analysis of state feedback digital control system.

Total No. of Lectures: 28

Lecture Wise Breakup		**Number of Lectures**
1.	**Introduction:** Control system terminology, computer based control, control theory (history & trends).	02
2.	**Signal processing in digital control:** Advantages of digital control, basic digital control scheme, principle of signal conversion, basic discrete-time signals, time domain & transfer function models, stability in z –plane, sampling, sampled spectra & aliasing, filtering, principles of discretization.	08
3.	**Models of digital control devices and system:** Z-domain description of sampled continuous, time plants, z-domain description of systems with dead-time, implementation of digital controllers.	04
4.	**Design of Digital Control algorithms:** Z-plane specifications of control system design, digital compensator design using frequency response and root locus plots, z-plane synthesis.	03
5.	**State Variable Analysis of Digital Control System:** State description of digital processors, state description of sampled continuous-time plants, solution of state difference equations controllability and observability.	06
6.	**Digital Control System with State Feedback**,: State feedback design, dead beat control by state feedback and dead beat observers, lyapunov stability analysis for discrete-time systems.	05

Lab Work:

Sr. No.	**Lab Contents**	**Lab Turns**
1.	Discrete time state space modeling for SISO system.	02
2.	Discrete time state space modeling for MIMO system.	02
3.	Design of state feedback for discrete time system.	02
4.	Design of state observer for discrete time system.	02
5.	Design of lead, lag and lag-lead compensator for discrete time system.	02
6.	Design of digital control systems with deadbeat response.	02
7.	Project	02

Course Outcomes: By the end of this course, the student will be able to:

CO1	Apply the concepts of signal processing and digital control, z-transformation.
CO2	Design digital control algorithms.
CO3	Perform state-variable analysis of digital control system
CO4	Design state feedback digital control system.
CO5	Execute stability analysis of the digital control systems.

Text Books

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	Digital Control and State variable methods, M. Gopal, Tata McGraw-Hill publishing company limited.	2008
2.	Discrete-Time Linear Systems: Theory and Design with Applications. G. Gu, Springer	2012

	Science & Business Media.	
3.	Discrete Time Control Systems, K. Ogata	1995

Reference Books:		
Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	Discrete control systems, Y. Okuyama, Springer London.	2014
2.	Advanced Discrete-Time Control, K. Abidi, J.X. Xu, Springer Singapore.	2015

Course Name	**:**	**Control Techniques in Power Electronics**
Course Code	**:**	**EER1114**
Credits	**:**	**3**
LTP	**:**	**3-0-0**
Course Objectives:		
At the end of this course, the students should be able to 1. Design Control Loops Of Power Electronic Convertors Using Different Perspectives 2. Apply the control techniques for design of realistic applications.		

Total No. of Lecture - 42

Lecture Wise Breakup		**Number of Lecture**
1.	**Convertor Transfer Functions** Basic AC modelling approach using small signal model, state space average model, circuit averaging and average switch model, modelling of pulse width modulator. Review of bode plots and its use in loop shaping. Transfer function of buck, boost and buck-boost convertors with non-idealities. Transfer functions of higher order converters. Physical origins of RHP zeroes/non minimum phase in transfer functions and its implications on controller design.	15
2.	**Voltage Mode Control** Effect of negative feedback on convertor transfer functions. Relative stability concepts for convertor transfer functions. Principles of controller design in frequency domain and methodology for loop shaping. Conventional controllers for transfer functions (PD, PI, PID). Input filter design and its effects on dynamics of power convertors. Hysteretic control.	15
3.	**Current Programmed control** Basics of current programmed control: Peak current mode control, average current mode control. Oscillations in current mode control and slope compensation. First order model for current programmed control. Accurate model for current programmed control. Effects and control advantages of current programmed control on the convertor transfer functions.	12

Course Outcomes: By the end of this course, the students will be able to	
CO1	Realize the concepts of converter transfer functions
CO2	Realize the voltage mode control of power electronic converters
CO3	Perform in-depth modelling of power electronic convertors.
CO4	Design complex control loop of power electronic convertors for both voltage mode and current programmed control

Suggested Books:

Sr. No.	**Name of Book/Authors/Publisher**	**Year of Publication/ Reprint**
1.	Robert W. Erickson & Dragan Maksimovic, Fundamentals of Power Electronics, second edition, Springer. ISBN 9788181283634	2014
2.	Frede Blaabjerg, Control of Power Electronic Convertors and Systems. Academic Press Volume 1-3	2018
3.	Andre S. Kislovsk, Richard Redl and Nathan O. Sokal Dynamic Analysis of Switching-Mode DC/DC Converters, VAN NOSTRAND REINHOLD	1991
4.	Byungcho Choi, Pulsewidth Modulated DC-to-DC Power Conversion (circuits dynamics and control design), IEEE Press John Wiley	2013

Program Core-V

Course Name	**:**	**Deregulated Power System**
Course code	**:**	**EER1105**
Credits	**:**	**3**
L T P	**:**	**3-0-0**
Course Objective:		
At the end of this course, the student is expected to be able to 1. Acquire knowledge of economic issues in power sector, power system de-regulation, restructuring, market reforms. 2. Understand transmission planning and pricing issues.		

No. of Lectures 42

Lecture wise breakup		**Number of Lectures**
1.	**POWER SECTOR IN INDIA** Evolution of integrated, monopoly, state electricity boards (SEBs), introduction to various institutions in Indian power sector such as CEA, planning commission, PFC, Ministry of Power, state and central Governments, REC, financial institutions, PTC, utilities and their roles, challenges before Indian power sector, electricity act 2003 and various National policies and guidelines under the act, introduction to Indian Energy Exchange and its working.	5
2.	**Deregulation of Electricity Supply Industries** Introduction to deregulation, different entities in deregulated electricity markets, background of deregulation around the world, benefits from competitive electricity markets, different key issues of competitive electricity markets, market Clearing Price (MCP) - Market operations: Day-ahead and Hour-Ahead Markets, Elastic and Inelastic demand, technical challenges, Power System Restructuring and electricity reforms in India, key features of electricity act 2003.	8
3.	**Market Models** Market Models based on energy trading, contractual agreement: Pool & Bilateral models, different independent models, role of ISO, market power, Bidding and auction mechanisms, optimal power flow, economical load dispatch and unit commitment in deregulated environment, market models in Indian market context and power trading in India.	7
4.	**Transmission Open Access and pricing issues** Power wheeling, transmission open access, cost component in transmission pricing, basic objectives, different methods of transmission pricing, Short run and long run marginal transmission price structure, development in international transmission pricing, reactive power pricing structure, and its calculation for generator's reactive support, numerical examples, impact of FACTS devices on transmission pricing.	7
5.	**Available transfer capability determination** Definitions, principles of ATC determination, factors affecting ATC, static and dynamic ATC, static ATC determination using DC power transfer distribution factors, AC power transfer distribution factors, ATC with line outage contingencies, LODFs with DC and AC, dynamic ATC and its determination, ATC enhancement with FACTS controllers, numerical examples.	7
6.	**Transmission congestion management** Transmission congestion, impact of transmission congestion, different methods of congestion management, financial transmission right, flow gate rights, market power and congestion issues, numerical examples, international experiences of transmission congestion management, security management: spinning reserves, interruptible load options.	8

Course Outcomes: By the end of this course, the student will be able to:	
CO1	Explain the economic issues in power sector and concept of power system de-regulation, restructuring and market reforms.
CO2	Justify the importance of transmission Open Access.
CO3	Apply the methods of transmission pricing and ATC calculation
CO4	Model and analyse congestion management under different conditions.

Suggested Books:		
Sr. No.	**Name of Book/Authors/Publisher**	**Year of Publication /Reprint**
1.	Lai Lio Lee, Power System restructuring and deregulation. John Wiley and Sons, UK	2012
2.	Bhattacharya K, Bollen MHT and Doolder JC, Operation of Restructured Power Systems, Kluwer Academic Publishers, USA	1998
3.	Shahidehpour M et al., Market Operations in Electric Power Systems, John Wiley and Sons	2002
4.	Ilic M, Power Systems Restructuring-Engineering and Economics, Kluwer Int. Series	2008
5.	Philipson Lorrin, Willis H Lee, Understanding electric utilities and de-regulation, Marcel Dekker Pub	2006

Course Name	**:**	**Advance Control Techniques in Power Electronics**
Course Code	**:**	**EER1125**
Credits	**:**	**03**
L T P	**:**	**3-0-0**

Course Objectives:

At the end of the course, the student should be able to:
1. Learn the concepts of modeling of power electronic converters.
2. Learn various linear control techniques for the various types of power electronics converters.
3. Learn various non-linear control techniques for the various types of power electronics converters.

Total No. of Lectures: 42

Lecture Wise Breakup		**Number of Lectures**
1.	**Modeling of DC-to-DC Power Converters** State space modeling and simulation of linear systems, Discrete time models, conventional controllers using small signal models of different converters.	08
2.	**Control Design Method of Power Converters** Sliding Mode & Fuzzy control, Variable structure control, Hysteresis controllers, Output and state Feedback switching controllers .	10
3.	**Linearized Model and Control of Power Converters** Linear Feedback Control, Controller Design by Pole Placement, Proportional-Derivative Control via State Feedback, State Feedback Control via Observer Design, GPI Controller Design for different converters.	12
4.	**Nonlinear Methods in the Control of Power Electronics Devices** Feedback Linearization, Passivity Based Control, Exact Error Dynamics Passive Output Feedback Control, Non-linear observers for power converters.	12

Course Outcomes: By the end of this course, the student will be able to:	
CO1	Apply the state space modeling concepts for different converters.
CO2	Design and analyze the variable structure control, hysteresis control and fuzzy control for the converters.
CO3	Design state feedback controls for the power electronic converters.
CO4	Apply non-linear control methods for different power electronic devices.
CO5	Apply non-linear observer for different power electronic devices.

Text Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	R.W. Erickson and D. Maksimovic, Fundamentals of Power Electronics, KLUWER Academic Publishers.	2004
2.	S.R. Hebertt and R.S. Ortigoza Control Design Techniques in Power Electronics Devices, Springer	2005

Course Name	**:**	**Advanced Electric Drives**
Course Code	**:**	**EER1115**
Credits	**:**	**3**
LTP	**:**	**2-0-2**
Course Objectives:		

At the end of this course, the students should be able to
1. Realize the concepts of advanced control strategies of induction and synchronous machine
2. Apply advanced strategies for the fast dynamical control of induction and synchronous motors

Total No. of Lecture - 28

Lecture Wise Breakup		**Number of Lecture**
1.	**Vector Control of Induction Machine** Vector Control of Induction Machine: Concept of Space Phasor, Principle of Decoupled Control, Rotor Flux Oriented Vector Control, Stator Flux Oriented Vector Control, Magnetizing Flux Oriented Vector Control. Torque Response. Flux Estimation Schemes. Sensorless Vector Control of Induction Motor.	10
2.	**Direct Torque Control (DTC) of Induction Machine** Principle of Direct Torque Control (DTC). Flux estimation scheme in stationary reference frame. Control block diagram of DTC with look up table. SVM-DTC of Induction Machine. Modifications and recent advances in DTC.	8
3.	**Vector Control of Synchronous Motor Drive** CSI Fed Vector Control, Vector Control by Current Regulated VSI, Dynamics of Vector Control in Synchronous Motor Drive, Equivalent Circuit, Torque Production. UPF Operation of Synchronous Motor, Cycloconverter Fed Synchronous Motor Drive.	10

Course Outcomes: By the end of this course, the students will be able to	
CO1	Realize vector control of induction machine and synchronous motor
CO2	Realize direct torque control of induction machine
CO3	Apply advanced control methods for control of Induction Machine and Synchronous Motor.
CO4	Apply advanced inverter modulation techniques for control of Induction Machine and Synchronous Motor.

Suggested Books:

Sr. No.	**Name of Book/Authors/Publisher**	**Year of Publication/ Reprint**
1.	Electric Motor Drives: Modeling Analysis & Control by R. Krishnan Pearson Education	2001
2.	Peter Vas, “Vector Control of AC Machines”, Clarendon Press Oxford , ISBN 0-19-859370-8.	1990
3.	Werner Leonhard, “Control of Electric Drives” Third Edition, Springer, ISBN 978-3-540-41820-7	2012
4.	Peter Vas, “Sensor less Vector and Direct Torque Control”, Oxford University Press , ISBN 0-19-856465-1.	1998

List of Experiments

Sl. No	**Experiment Name**	**No of Lab Turns**
1.	Simulate and perform vector control of induction machine	3
2.	Simulate and perform vector control of synchronous machine	3
3.	Simulate and perform direct torque control of induction machine	3
4.	Simulate and perform SVM-DTC of induction machine	3
5.	Simulate and perform direct torque control of induction machine with different flux estimation techniques	2

Program Core-VI

Course Name	**:**	**EHV Transmission**
Course Code	**:**	**EER1106**
Credits	**:**	**3**
L T P	**:**	**3 0 0**
Course Objectives:		
In this course the students shall be 1. Made conversant with EHVAC and HVDC transmission concept, static var system, corona interference in EHVAC and HVDC transmission. 2. Able to understand and design the harmonic filters 3. Able to perform power flow analysis in AC/DC systems		

No. of Lectures-42

Lecture wise breakup		**Number of Lectures**
1.	**Overview:** Comparison of EHV AC and DC transmission, description of DC transmission systems, modern trends in AC and DC transmission. Economic Comparison of HVAC and HVDC. Bulk power transmission at extra high voltages. Comparison of transmission system losses of HVAC and HVDC Transmission systems.	03
2.	**EHV AC Systems:** Limitations of extra-long AC transmission, Voltage profile and voltage gradient of conductor, Electrostatic field of transmission line, Reactive Power planning and control, EHV cable transmission system.	06
3.	**Static VAR System:** Reactive VAR requirements, Static VAR systems, SVC in power systems, design concepts and analysis for system dynamic performance, voltage support, damping and reactive support.	08
4.	**HVDC System:** Converter configurations and their characteristics, DC link control, converter control characteristics; Monopolar operation, converter with and without overlap, smoothing reactors, transients in DC line, converter faults and protection, HVDC Breakers.	08
5.	**Corona and Interference:** Corona and corona loss due to EHV AC and HVDC, Radio and TV interference due to EHV AC and HVDC systems, methods to reduce noise, radio and TV interference.	06
6.	**Harmonic Filters:** Generation of harmonics, design of AC filters, DC filters	03
7.	**Power flow analysis in AC/DC systems:** Component models, solution of DC load flow, per unit system for DC quantities, solution techniques of AC-DC power flow equations, Parallel operation of HVDC/AC systems, Multi terminal systems.	08

Course Outcomes: By the end of this course, the student will be able to:	
CO1	Explain the concepts of EHVAC & HVDC transmission and different var schemes for compensation
CO2	Investigate corona and radio interference in EHVAC and HVDC transmission
CO3	Do the harmonic analysis and design of AC/DC filter
CO4	Perform power flow analysis in AC and DC systems

Text Books:	
1.	S. S. Rao EHV-AC,HVDC, Transmission & Distribution Engineering,-2009

Recommended Books:	
1.	Padiyar K.R., HVDC Power Transmission Systems, Wiley Eastern Ltd., New Delhi- 1990
2.	Kimbark E.," Direct Current Transmission", Vol-I, John-Wiley & sons, NY- 1971
3.	Arrillaga J., HVDC Transmission, IEE Press, London- 1998

4.	Begamudre R.D., EHV AC Transmission Engineering, Wiley Eastern Press
5.	Arrillaga J. and Smith B.C., AC-DC Power System Analysis, IEE Press, London.

Course Name	**:**	**Non-linear Control Systems**
Course Code	**:**	**EER1126**
Credits	**:**	**03**
L T P	**:**	**3-0-0**

Course Objectives:

At the end of the course, the student should be able to:
1. Learn and apply the concepts of non- linear control for qualitative analysis.
2. Understand the controllability and observability of the non –linear systems under different disturbances.
3. Understand the stability analysis of the non-linear control systems.

Total No. of Lectures: 42

Lecture Wise Breakup		**Number of Lectures**
1.	**Introduction:** General Properties of linear and non-linear systems, perturbation theory, and perturbation dynamics, controllability and observability of non-linear systems, Lipschitz continuity, existence and uniqueness of solution of non-linear systems.	08
2.	**Modeling of non-linear systems:** Modeling of simple mechanical systems, degree-of freedom, configuration spaces and state-space representation, equilibrium points/operating points, Jacobian linearization.	05
3.	**Mathematical notions:** Notion of vector field, trajectories, vector field plot, phase plane portrait, positively invariant sets and classification of equilibrium points.	04
4.	**Qualitative analysis of second order systems:** Second-order systems, periodic solution, Bendixson's theorem and Poincare-Bendixson criteria.	07
5.	**Notions of stability of non-linear systems:** Lyapunov theorem, small gain theorem, describing function method, asymptotic stability, exponential stability.	05
6.	**Lyapunov's stability notions and its variants:** Stability analysis using Lyapunov's direct and indirect method, La Salles's invariance principle and its examples.	05
7.	**Non-Linear Control techniques:** Feedback linearization, variable structure control, nonlinear observers for SISO, MIMO systems.	08

Course Outcomes: By the end of this course, the student will be able to:	
CO1	Apply the concepts of modeling of non-linear systems.
CO2	Design and analyze the second order systems.
CO3	Design and analyze the stability of non-linear systems.
CO4	Implement Lyapunov's stability criterias on the non-linear problems.
CO5	Design various control techniques for non-linear control systems.

Text Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	Slotine, J.J and Li W.P., 'Applied Nonlinear control', Prentice Hall.	1991
2.	Khalil H, 'Nonlinear Systems', 3rd edition, Macmillan.	2002
3.	Marquez HJ. Nonlinear control systems: analysis and design. Hoboken: Wiley-Interscience.	2003
4.	Astolfi A, Marconi L. Analysis and Design of Nonlinear Control Systems.	2008

Reference Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	Fantoni I, Lozano R. Non-linear control for underactuated mechanical systems. Springer Science & Business Media.	2002
2.	Isidori, A. 'Nonlinear Control Systems', 2nd edition Springer.	1989

Course Name	**:**	**Power Electronics Applications in Power Systems**
Course Code	**:**	**EER1116**
Credits	**:**	**3**
LTP	**:**	**3-0-0**

Course Objectives:

At the end of this course, the students should be able to
1. Apply power electronic convertors for compensation in transmission lines and non-linear loads
2. Apply power electronic convertors for harmonic reduction

Total No. of Lecture - 42

Lecture Wise Breakup		Number of Lecture
1.	**Transmission Systems Compensation** Discussion and comparative analysis of various transmission system compensators: switched shunt reactor, switched shunt capacitor, series capacitor, synchronous condenser, TCR, TSC. Classification of compensators: surge impedance compensators and line length compensators. Voltage regulation with SVC, TCSC, SPS, STATCOM, DVR, UPFC. Power flow control with HVDC-Light. Types of VSC used in transmission compensation: conventional six step VSC, NPC-VSC, Multilevel VSC, PWM-VSC.	21
2.	**Power Electronics for Harmonic Reduction and Compensation** Concepts of non-linear loads and electric power conditioning, Types of Power Sources, Power Electronic Converter Harmonics. Multi pulse methods for harmonic elimination: delta/wye, delta zigzag/Fork, Delta Polygon, Delta/delta/Double Polygon, Delta/Hexagon. Auto Wound Transformers, Interphase and Current Balancing Transformers. Calculation of Harmonics, Harmonic Standards. Active Power Line Conditioners: Passive filters and limitations, active filters for harmonic and reactive power compensation in two wire, three wire and four wire ac systems, Shunt Active Filter, Hybrid and Series Active Filters.	21

Course Outcomes: By the end of this course, the students will be able to

CO1	Realize the concepts of various transmission system compensators
CO2	Design power electronic convertors for compensation in transmission lines
CO3	Realize the concepts of non-linear loads and electric power conditioning
CO4	Design power electronic convertors for harmonic compensation to improve power quality

Suggested Books:

Sr. No.	Name of Book/Authors/Publisher	Year of Publication/ Reprint
1.	Enrique Acha, Power Electronic Control in Electrical Systems, Newnes, ISBN-0750651261	2001
2.	H Akagi, E.H. Watanabe and M Aredes, “Instantaneous power Theory and applications to Power Conditioning”, IEEE Press, John Wiley and sons Incorporate.	2007
3.	J Arrilaga and N.R Watson, “Power System Harmonics”, John Wiley and Sons Ltd	2003

Program Elective-I

Course Name	**:**	**Static Reactive Power Control and FACTS**
Course Code	**:**	**EER1201**
Credits	**:**	**3**
L T P	**:**	**3 0 0**
Course Objectives:		
In this course the students are expected to learn 1. The basic concepts of reactive power control in transmission. 2. The various FACTS devices 3. Transformer, Harmonics and filters		

Total No. of Lectures-42

Lecture wise breakup		**Number of Lectures**
1.	Introduction: Principles of reactive power control in load, and transmission line compensation, series and shunt reactive power compensation. Concepts of Flexible AC Transmission System (FACTS).	06
2.	Power Semiconductor Devices, Voltage-sourced converters, Self and line-Commutated Current-Sourced Converters.	08
3.	Static Shunt Compensators, SVC and STATCOM, Operation and Control of TSC, TCR, STATCOM, Compensator Control, Comparison between SVC and STATCOM, STATCOM for transient and dynamic stability enhancement	06
4	Static Series Compensation, GCSC, TSSC, TCSC and SSSC, Operation and Control, External System Control for Series Compensators, SSR and its damping, Static Voltage and Phase Angle Regulators, TCVR and TCPAR, Operation and Control	06
5.	UPFC and IPFC, The Unified Power Flow Controller, Operation, Comparison with other FACTS devices, control of P and Q, Dynamic Performance, Special Purpose FACTS Controllers, Interline Power Flow Controller, Operation and Control	08
6.	Special topics: TCBR, Sen Transformer, Harmonics and filters	08

Course Outcomes: By the end of this course, the student will be able to:	
CO1	Understand and apply the basic concepts of reactive power transmission, FACTS,
CO2	Design voltage sourced converters, self and line commutated current sourced converters
CO3	Perform modeling of conventional compensation devices
CO4	Perform modeling and analysis of special compensation devices in electrical power system

Text Books:	
1.	N.G. Hingorani and L. Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems, Standard Publishers-Distributors.-2001
2.	R.K. Varma and R.M. Mathur, “Thyristor Controlled Flexible AC Transmission System” IEEE Press- 2002

Reference Books:	
1.	Miller T.J.E., “Reactive Power Control in Electric Systems”, John Wiley, 1982.

Course Name	**:**	**Neural Networks and Fuzzy Logic**
Course Code	**:**	**EER1202**
Credits	**:**	**03**
L T P	**:**	**3-0-0**

Course Objectives:
At the end of this course, the student should be able to acquire knowledge of 1. Neural networks and fuzzy systems, different structure of neural networks, development and implementation of algorithm, and their applications. 2. Design neural networks and fuzzy systems for different applications.

Total No. of Lectures – 42

	Lecture wise breakup	**Number of Lectures**
1.	**Introduction** Biological neuron, Models of Artificial Neural Networks (ANN), Characteristics of Neural Networks, Different types of learning of neural network.	04
2.	**Fundamental Models of ANN** Mcculloch–Pitts, Hebbian, Perceptron, Delta, Owstrar, Boltzman, Adaline, Madaline: Architecture, Algorithm and Applications.	05
3.	**Feed Forward Networks** Back propagation, Radial basis function- Architecture, Algorithm and Applications.	04
4.	**Self Organizing Feature Map** Kohonen Self Organizing Maps, Learning Vector Quantization (LVQ), Max. Net, Hamming Net-Architecture, Algorithm and Applications.	04
5.	**Feedback Networks** Hopfield Net- Architecture, Training Algorithm and Application for discrete and continuous net.	03
6.	**Associative Memory Networks** Hetero, Auto and Bi-directional Associative Networks-Architecture, Algorithm and Applications.	03
7.	**Application of Neural Networks** Application of neural network in engineering areas.	03
8.	**Introduction of Fuzzy Systems** Fuzzy logic, classical sets and fuzzy sets, operations on fuzzy sets, properties of fuzzy sets, crisp and fuzzy relations, membership functions, fuzzification, defuzzification.	09
9.	**Fuzzy Rule Based System** Formation of rules, decomposition of rules, aggregation and properties of fuzzy rules, fuzzy inference system.	04
10.	**Applications of Fuzzy Logic** Fuzzy logic applications in various areas including power systems, image processing, control systems, industries etc.	03

Course Outcomes: By the end of this course, the student will be able to:	
CO1	Design a model of ANN
CO2	Apply the various types of ANN model in engineering areas
CO3	Design rule based fuzzy logic system
CO4	Apply fuzzy logic controllers in engineering areas

Suggested Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	Fundamental of Neural Networks-Architectures, Algorithm and Applications by Laurene Fausett, Pearson,.	1993

2.	Neural Networks- A comprehensive foundation by Simon Haykin, Macmillan Publishing Company, New York,.	1994
3.	Neural Networks-A classroom approach by Satish Kumar, The McGraw-Hill Companies,.	2005
4.	Fuzzy Logic with Engineering Applications by Timothy J. Ross Wiley Student Edition,.	2010
5.	Introduction to Neural Networks using MATLAB by S.N. Sivanandam, S. Sumati and S.N. Deepa, Tata McGraw Hill,.	2006
6.	Introduction to Fuzzy Logic using MATLAB by S.N. Sivanandam, S. Sumati and S.N. Deepa, Springer,.	2007

Course Name	**:**	**Power System Planning & Reliability**
Course Code	**:**	**EER1203**
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:
The students are expected to learn the 1. Fundamentals of power system planning and reliability, 2. Short term load and pricing forecasting, planning in deregulated environment, 3. Power system planning with hybrid sources.

Total No. of Lectures-42

Lecture wise breakup		**Number of Lectures**
1.	**Fundamentals of Power System Planning** Planning Process, Generation planning, Transmission planning, Least-cost planning, Risks and making choices in planning Power system reliability;	06
2.	**Fundamentals of Power System Reliability** Reliability assessment, basic probability methods as applied to generating capacity, introduction, the generation system model, loss of load indices, equivalent forced outrage rate, scheduled outrages, evaluation methods on period bases, Component reliability, logic diagrams, monotonic structure, state space method	08
3.	**Short Term Load and Price Forecasting** Short term load forecasting; Short term market price forecasting; Regression models for load forecasting; Artificial neural networks for load forecasting, load forecast uncertainty, forced outage rate uncertainty, loss of energy indices, system risk indices, other approaches for forecasting such as data mining approaches; Issues in load and price forecasting	08
4.	**Reliability analysis of interconnected System:** Introduction, probability array method in two interconnected systems, equivalent assisting unit approach to two interconnected systems, factors affecting the emergency assistance available through the interconnections, variable reserve versus maximum peak load reserve, reliability evaluation in three interconnected systems, multi-connected systems, frequency and duration approach.	08
5.	**Transmission System reliability analysis:** Composite generation and transmission systems, introduction, radial configurations, conditional probability approach, network configurations, state selection, system and load point indices, application to practical systems, data requirements for composite system reliability evaluation.	06
6.	**New Challenges of Power System Planning & reliability** Probabilistic power system planning. Probabilistic power system reliability assessment; Probabilistic power system security assessment; Combining conventional and renewable sources for optimal power system planning in deregulated environment.	06

Course Outcomes: The students are able to	
CO1	Explain the fundamentals of power system planning and reliability
CO2	Perform the load forecasting using different techniques
CO3	Investigate the transmission system reliability
CO4	Model probabilistic power system planning

Text Books:	
1.	M. Ilic, F. Grliana, L. Fink, Power System Restructuring- (Kluwer Academic Publishers), 1998.
2.	R. L. Sullivan , Power System Planning- (McGraw Hill), 1977
3.	Reliability Assessment of Electric Power Systems – R. Billinton, R.N. Allan (2nd Edition, Plenum Press, New York) 1992.

Reference Books:	
1.	Conflicting Objectives and Risk in Power System Planning – E.O. Crousillat, P. Dorfner, P. Alvarado, H.M.

	Merrill, (IEEE Trans, Power Systems, Vol. 8, No.3, pp 887-893) August 1993.
2.	IEEE transactions on the Topic Power System Planning in Deregulated Environment.
3.	Reliability Engineering – R. Billinton .

Course Name	**:**	**Smart Grid Technologies**
Course Code	**:**	**EER1204**
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

The students are expected to understand

1. The fundamentals of smart grid technologies such as smart measurements, smart technology for smart substations, micro grid and distributed energy sources
2. Power quality management in smart grid, information and communication technology for smart grid.

Total No. of Lectures-42

Lecture wise breakup		**Number of Lectures**
1.	**Introduction to Smart Grid:** Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid, Concept of Resilient & Self-Healing Grid, Present development & International policies in Smart Grid. Case study of Smart Grid. CDM opportunities in Smart Grid.	04
2.	**Smart Grid Technologies:** Part 1: Introduction to Smart Meters, Real Time Pricing, Smart Appliances, Automatic Meter Reading (AMR), Outage Management System (OMS), Plug in Hybrid Electric Vehicles (PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation, Phase Shifting Transformers.	08
3.	**Smart Grid Technologies**: Part 2: Smart Substations, Substation Automation, Feeder Automation. Geographic Information System (GIS), Intelligent Electronic Devices (IED) & their application for monitoring & protection, Smart storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage, Wide Area Measurement System (WAMS), Phase Measurement Unit (PMU).	08
4.	**Micro grids and Distributed Energy Resources**: Concept of micro grid, need & applications of microgrid, formation of micro grid, Issues of interconnection, protection & control of micro grid. Plastic & Organic solar cells, thin film solar cells, Variable speed wind generators, fuel cells, micro turbines, Captive power plants, Integration of renewable energy sources.	07
5.	**Power Quality Management in Smart Grid**: Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.	08
6.	**Information and Communication Technology for Smart Grid:** Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN). Bluetooth, Zig-Bee, GPS, Wi-Fi, Wi-Max based communication, Wireless Mesh Network, Basics of CLOUD Computing & Cyber Security for Smart Grid. Broadband over Power line (BPL). IP based protocols.	07

Course Outcomes: The students are able to	
CO1	Explain and analyze smart grid technologies such as smart measurements, smart technology for smart substations.
CO2	Understand micro grid and distributed energy sources
CO3	Perform power quality management in smart grid
CO4	Understand information and communication technology for smart grid.

Text Books:	
1.	Clark W. Gellings, "The Smart Grid: Enabling Energy Efficiency and Demand Response", CRC Press Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama," Smart Grid: Technology and Applications", Wiley 2020

Reference Books:	
1.	Ali Keyhani, Mohammad N. Marwali, Min Dai “Integration of Green and Renewable Energy in Electric Power Systems”, Wiley 2009
2.	Clark W. Gellings, “The Smart Grid: Enabling Energy Efficiency and Demand Response”, CRC Press Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu-2020
3.	Akihiko Yokoyama,“ Smart Grid: Technology and Applications”, Wiley
4.	Jean Claude Sabonnadière, Nouredine Hadjsaïd, “Smart Grids”, Wiley Blackwell
5.	Tony Flick and Justin Morehouse, “Securing the Smart Grid”, Elsevier Inc. (ISBN: 978-1-59749-570-7)
6.	Peter S. Fox-Penner, “Smart Power: Climate Change, the Smart Grid, and the Future of Electric Utilities”

Course Name	**:**	**Distribution System Operation and Planning**
Course Code	**:**	**EER1205**
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

The students are expected to
1. Understand the fundamental concepts of distribution system,
2. Model and analyze of distribution system components.
3. Understand the distribution system reliability.

Total No. of Lectures-42

Lecture wise breakup		**Number of Lectures**
1.	**Introduction:** Distribution System, Distribution Substations, Radial distribution feeders, Distribution Feeder Electrical Characteristics, nature of load,	03
2.	**Distribution System Line Modeling:** Exact Line Segment Model, The Modified Line Model, The Approximate Line Segment Model	06
3.	**Transformer Modeling:** Delta–Grounded Wye, Grounded Wye–Grounded Wye, Delta–Delta configuration	07
4.	**Load Modeling:** Constant Real and Reactive Power Loads, Constant Impedance Loads, Constant Current Loads, composite load	09
5.	**Power flow analysis:** The Ladder Iterative Technique for linear and nonlinear loads, balanced and unbalanced load, short circuit studies	09
6.	**Distribution System reliability analysis** Interruption indices, probability distributions of reliability indices of distribution systems-parallel and meshed network	08

Course Outcomes: The students are able to	
CO1	The students are able to understand the basic concepts of distribution system.
CO2	The students are able to develop accurate models for major components of a distribution system.
CO3	The students are able to implement the analysis techniques for steady-state and short-circuit conditions.
CO4	The students are able to do the reliability analysis of simple distribution system

Text Books:	
1.	Distribution System Modeling and Analysis- William H. Kersting-2017.
2.	Reliability Evaluation of Power Systems- Roy Billinton and Ronald N. Allan-1992

Reference Books:	
1.	Electrical Power Distribution System- Pabla, A.S, 5th edition,Tata McGraw hill, 2004
2.	Electrical Power Distribution System Engineering- Tuvar Goner, McGraw hill, 1986
3.	Electric Distribution Systems- Abdelhay A. Sallam and Om P. Malik, wiley publication

Course Name	**:**	**Control Techniques for Microgrid**
Course Code	**:**	**EER1206**
Credits	**:**	**03**
L T P	**:**	**3-0-0**
Course Objectives:		
At the end of this course, the student shall be able to:		
1. Learn the fundamentals of microgrid. 2. Learn the modelling of different types of microgrid. 3. Learn the several control techniques for the different kinds of microgrid.		

Total No. of Lectures: 42

Lecture Wise Breakup		**Number of Lectures**
1.	**Brief introduction and Concepts of Microgrid** Overview of Microgrids, Concept of Microgrids, Microgrid and distributed generation, Microgrid vs Conventional Power System, AC and DC Microgrid with Distributed Energy Resources, Islanded and grid connected microgrid.	06
2.	**Types of Microgrid system** Modeling of converters in microgrid power system (AC /DC and DC/AC Converters Modeling), Modeling of Power Converters in Microgrid Power System (DC/DC Converter Modeling and Control), Modeling of Renewable Energy Resources (Modeling of Wind Energy System), Modeling of Renewable Energy Resources (Modeling of Photovoltaic System), Modeling of Energy Storage System	06
3.	**Microgrid Dynamics and Modeling** Microgrid Operation Modes and Standards, Microgrid Control Architectures, Intelligent Microgrid Operation and Control, microgrid modeling.	10
4.	**Control of DC Microgrid System** Control of DC Microgrid System, Applications of DC Microgrids, Stability in Microgrid, DC microgrid, stabilization using nonlinear techniques.	10
5.	**Islanded and Grid Connected Microgrid** Sliding mode control, fuzzy logic, PID control of microgrid, examples.	10

Course Outcomes: By the end of this course, the student will be able to:	
CO1	Apply the concepts of fundamentals of microgrid.
CO2	Apply the concepts of modeling to the various kinds of microgrid.
CO3	Apply the concepts of control of DC microgrid.
CO4	Design and analyze the control techniques for islanded microgrid.
CO5	Design control techniques for grid connected microgrid.

Text Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	Tabatabaei, Naser Mahdavi, Ersan Kabalci, and Nicu Bizon, eds. Microgrid architectures, control and protection methods. Springer.	2019
2.	Bevrani, Hassan, Bruno François, and Toshifumi Ise. Microgrid dynamics and control. John Wiley & Sons.	2017

Reference Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	Gao, David Wenzhong. Energy storage for sustainable microgrid. Academic Press.	2015

Course Name	**:**	**Adaptive Control**
Course Code	**:**	**EER1207**
Credits	**:**	**03**
L T P	**:**	**3-0-0**

Course Objectives:

At the end of the course, the student should be able to:

1. Learn real time parameter estimation and deterministic self tuning regulators.
2. Understand the stochastic and predictive self tuning regulators.
3. Understand the model reference adaptive system, stochastic adaptive control, auto-tuning and gain scheduling.

Total No. of Lectures: 42

Lecture Wise Breakup		Number of Lectures
1.	**Introduction** Effects of process variations, Adaptive schemes, adaptive control problems, applications.	04
2.	**Real Time Parameter Estimation** Least squares and regression models estimating parameters, simulation of recursive estimation.	05
3.	**Deterministic Self Tuning regulators** Pole placement design, indirect self tuning regulators, continuous time self tuners, direct self tuning regulators, disturbances with known characteristics.	07
4.	**Stochastic and Predictive Self Tuning Regulators** Design of minimum variance and moving average controllers, stochastic self tuning regulators, Linear quadratic STR Adaptive Predictive control.	06
5.	**Model Reference Adaptive Systems** MIT Ruler determination of adaptive gain, Lyapnov theory, Design of MRAS using Lyapnov theory, applications to adaptive control, Output feedback relation between MRAS and STR.	07
6.	**Properties of Adaptive Systems** Nonlinear dynamics, adaptation of a feedforward gain, analysis of indirect discrete time self tuners, Averaging, application of averaging techniques. Averaging in stochastic systems, robust adaptive controllers.	03
7.	**Stochastic Adaptive Control** Multistep decision problems, stochastic adaptive problem dual control, suboptimal strategies.	03
8.	**Auto-tuning** PID Control, auto tuning techniques, transient response methods, methods based on relay feedback, relay oscillations.	04
9.	**Gain Scheduling** Principles, design of gain scheduling controllers, applications of gain scheduling.	03

Course Outcomes: By the end of this course, the student will be able to:

CO1	Apply the concepts of real time parameter estimation and deterministic self tuning regulators.
CO2	Design stochastic and predictive self tuning regulators and model reference adaptive system.
CO3	Analyze the properties of adaptive systems.
CO4	Implement stochastic adaptive control.
CO5	Implement auto-tuning and gain scheduling for their research.

Text Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1.	K.J Astrom and B. Wittenmark , Adaptive control, Second Edition, Eaglewood, cliffs.	2013
2.	P.R Kumar and Pravin Varaiyar, Stochastic systems – Estimation, Identification and adaptive control.	2015

3.	M. Gopal, Modern Control System Theory, New Age International (P) Ltd.	2005
4.	KJ Astrom, Introduction Stochastic Control Theory, Academic Press.	2012

Reference Books:		
Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	Shankar Sastry , Adaptive Control: Stability, convergence and Robustness, Prentice Hall.	1990

Course Name	:	**Digital Signal Processing**
Course Code	:	**EER1208**
Credits	:	**3**
LTP	:	**3-0-0**

Course Objectives:
At the end of this course, the students should be able to 1. Understand the concepts of digital signal processing and transformation techniques 2. Apply concepts of digital signal processing to the design of digital filters

Total No. of Lecture - 42

Lecture Wise Breakup		**Number of Lecture**
1.	**Signals and Time Domain Representation** Classification of signals, typical signal processing operations, typical signal processing applications, why digital signal processing. Discrete- time signals, operations on sequences, the sampling process, discrete-time systems, time-domain characteristics of LTI discrete-time systems, state space representation of LTI discrete time systems. Frequency response, the transfer function. Digital two-pairs stability test.	10
2.	**Transformations** Domain representation of signals: the discrete-time Fourier transform, discrete Fourier transform, computation of the DFT of real sequences, linear convolution using the DFT, the z- transform, the inverse z- transform	8
3.	**Digital Processing of Continuous Time Signals** Sampling of continuous time signals, analysis filter design, anti- aliasing filter design, reconstruction filter design.	8
4.	**Digital Filters** Block diagram representation, signal flow graph representation, equivalent structures, Basic FIR digital filter structures, Basic IIR filters structures, all pass filters, tunable structures. Impulse invariance method of IIR filter design, bilinear transform method of IIR filter design, design of filter IIR notch filters, FIR filter design based on truncated Fourier series, FIR filter design based on frequency sampling approach, computer-aided design of digital filters.	16

Course Outcomes: By the end of this course, the students will be able to	
CO1	Realize the concepts of digital signal processing and transformation techniques
CO2	Apply various transformation and processing techniques for conversion of analog signals into discrete and digital domain
CO3	Apply the concepts of digital signal processing to design of digital filters

Suggested Books:

Sr. No.	**Name of Book/Authors/Publisher**	**Year of Publication/ Reprint**
1.	Mitra, Sanjit .k, Digital Signal Processing, Tata-McGraw-hill edition.	1997
2.	Antoniou, A., Digital Filters: Analysis & Design McGraw hill Book company.	1979

Course Name	**:**	**Modern Control Systems**
Course Code	**:**	**EER1209**
Credits	**:**	**03**
L T P	**:**	**3-0-0**

Course Objectives:

At the end of the course, the student should be able to
1. learn the modeling concepts of system using state space
2. learn the optimal control techniques, digital control systems and non-linear systems.

Total No. of Lectures: 28

	Lecture Wise Breakup	**Number of Lectures**
1.	**Introduction** Control systems design requirements, classical versus modern approaches of design.	02
2.	**State Space Representation** Concepts related to state space, state space representation, state transition matrix, solution of linear time invariant and linear time varying state equations, canonical forms.	03
3.	**Control System Design in State Space** Controllability, pole placement design using full state feedback-regulator and tracking systems, observers, observability and compensators, full order and reduced order observers.	06
4.	**Linear Optimal Control** Optimal control problem, infinite time linear optimal regulator design, optimal control of tracking systems (Riccati equation based designs).	06
5.	**Digital Control Systems** Basic concepts, z-transform, stability, performance, state space modeling and solution of linear digital equations, design using pole placement, regulators and observers and compensators, linear optimal control of digital systems, digital Kalman filters and optimal design of compensators.	07
6.	**Nonlinear Control Systems** Sources of nonlinearities and characteristics of nonlinear systems, describing function method, phase plane analysis, Lyapunov stability theory.	04

List of Experiments

S.NO.	**Lab Contents**	**Lab Turns**
1.	State space modeling of continuous time system and study of stability and state and output responses	01
2.	Pole placement design using state feedback for regulator and tracking systems	01
3.	Full and reduced order observer design	02
4.	State space modeling of discrete time system and study of responses	02
5.	Pole placement design for regulator and tracking discrete time systems	02
6.	Observer design for discrete time systems	02
7.	Describing function analysis of nonlinear systems	02
8.	Phase plane analysis of nonlinear systems	02

Course Outcomes: By the end of this course, the student will be able to:

CO1	Apply the modeling concepts of system using state space.
CO2	Design optimal control techniques
CO3	Design digital control system
CO4	Implement and analyse the stability of non-linear systems.

Suggested Books:		
Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	Ashish Tewari, Modern Control Design with MATLAB and SIMULINK, John Wiley and Sons Ltd	2002
2	K. Ogata, Modern Control Engineering, PHI.	2014
3	M. Gopal, Modern Control System Theory, New Age International (P) Ltd.	2005
4	M. Gopal, Digital Control and State Variable Methods, TMH.	2003
5	William L. Brogan, Modern Control Theory, Pearson Education India.	2011

Course Name	**:**	**Power System Operation and Control**
Course Code	**:**	**EER1210**
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives: The students undergoing this course are expected to learn the concepts of

1. Learn analytical methods and numerical techniques for solving operation-related problems of power system operation, e.g security, economic dispatch, unit commitment frequency control
2. Learn fundamentals of energy management systems and Control techniques.
3. Model and solve optimal power flow problem under different conditions.

Total No. of Lectures-42

	Lecture wise breakup	**Number of Lectures**
1.	**Power Systems Operational Security and Dispatch** Review of security concept and state of operation, generation dispatch; dynamic security, economic load dispatch.	05
2.	**Frequency Control and AGC** Review of theory of frequency dynamics. Multi-area frequency dynamics, Load-frequency and tie-line power flow control. Theory of Automatic Generation control, AGC implementation methods.	07
3.	**Interconnected Systems Operation** Need of system interconnection. Operating policies, Economic interchange, Optimal multi-area Operation.	07
4.	**Unit Commitment** Priority lists, Integer Programming, Dynamic Programming, Lagrangian Relaxation, unit commitment with renewable energy (single & multi-objective)	07
5.	**Energy Management Systems and Real-Time Control** Energy management systems, Software systems, Computer hardware resources and configurations. Data management. Communications and distributed computing. Expert systems for contingency and security evaluation, event analysis, system restoration and reactive control. Short range load forecasting.	09
6.	**Optimal Power Flow** Introduction to Optimal Power Flow Techniques and Optimal Power Flow with conventional sources, Optimum Scheduling and Dispatch Of Power Systems with Renewable Generations, Reactive Power Management in Power Systems Integrated with Renewable generation, Role of Stochastic Optimization for Power System Operation and Decision Making	07

Course Outcomes: The students after undergoing this course will be able to:

CO1	apply the concepts of power systems operation, security and dispatch and unit commitment
CO2	do the frequency control and AGC in single area and Interconnected Systems Operation
CO3	understand energy management Systems in power system
CO4	model optimal power flow with conventional and renewable resources

Suggested Books:

1.	Wood and Wollenberg "Power Generation Operation and Control", John Wiley, 1984.
2.	OI Elgerd "Electric Energy Systems, Theory", McGraw Hill, 1983
3.	Mahalanabis et al., "Computer-aided power system analysis" Tata McGraw, 1988.
4.	Anderson &Fouand "Power system control and stability" Lowa State University Press, 1977.
5.	"Fundamentals of supervisory systems" IEEE Tutorial Course Text, 91EH0337-6PWR, 1991.

Course Name	**:**	**Discrete Time Control Systems**
Course Code	**:**	**EER1211**
Credits	**:**	**3**
LTP	**:**	**3-0-0**
Course Objectives:		
At the end of this course, the students should be able to 1. Learn various concepts of discrete time systems 2. Design controller for discrete time systems		

Total No. of Lecture - 42

Lecture Wise Breakup		**Number of Lecture**
1.	**Introduction and z-Transforms** Quantizing and Quantization Error, data acquisition, conversion and distribution systems. z transforms, properties of Z transforms, inverse z transforms, difference equations with z transforms.	06
2.	**z Plane Analysis** Impulse sampling, z-transform by convolution integral, reconstruction of original signal from sampled signal, realization of digital controllers and digital filters.	12
3.	**Design of Discrete Time Control Systems** Mapping between s-plane and z-plane, stability analysis in z-plane, transient and steady state response, design with root locus and frequency response, analytical design methods. State space representation of discrete time systems, solution of state space equations, pulse transfer function matrix, discretization of continuous time state space equations, lyapunov stability analysis.	12
4.	**Pole Placement and Observer Design** Controllability and observability in discrete domain, transformations in state space analysis. Design through pole placement, state observers.	12

Course Outcomes: By the end of this course, the students will be able to	
CO1	Realize the concept of Z transform
CO2	Apply various transformation and processing techniques for conversion of analog signals into discrete and digital domain.
CO3	Design controller for discrete time systems using various methods.
CO4	Implement and analyse the stability of discrete time systems.

Suggested Books:		
Sr. No.	**Name of Book/Authors/Publisher**	**Year of Publication/ Reprint**
1.	Ogata, K. Discete-Time Control Systems, Prentice-Hall India	1987
2.	G.F.Franklin, J.D. Powel and M.L. Workmen, Digital Control of Dynamic Systems, Joh Wiley & Sons	1997
3.	Kuo, B.C., Digital control systems, Orlando Florida: Saunders College Publishing	1977

Course Name	**:**	**Feedback Control of Dynamical Systems**
Course Code	**:**	**EER1212**
Credits	**:**	**3**
LTP	**:**	**3-0-0**

Course Objectives:

At the end of this course, the students should be able to
1. Learn concepts of feedback control
2. Analyze and design feedback controllers for dynamical systems

Total No. of Lecture - 42

Lecture Wise Breakup		**Number of Lecture**
1.	**Feedback Theory** Brief history of feedback control, dynamical models and dynamical response, system modeling, effect of pole locations and time domain specifications, effect of zeroes. Properties of feedback, control of steady state and dynamic error. Effect of discretization on system responses.	06
2.	**Feedback Control Design** Root locus design of feedback system, design with dynamic compensation, frequency response design method, stability margins, closed loop frequency response. State space design advantages, control law design for full state feedback, selection of pole locations, estimator design. Combining control law and estimator for design of compensator, integral control and robust tracking.	12
3.	**Digital Control** Digitization, dynamic analysis of discrete systems, design using discrete equivalents, hardware characteristics and sample rate selection.	12
4.	**Non-Linear Systems** Analysis of non-linear systems through linearization. Equivalent gain analysis using root locus. Equivalent gain analysis using frequency response, describing functions.	12

Course Outcomes: By the end of this course, the students will be able to

CO1	Realize the concept of feedback control system
CO2	Apply concepts of feedback control to dynamical systems.
CO3	Analyze and design feedback controllers for linear and non-linear dynamical systems
CO4	Analyze dynamical discrete systems

Suggested Books:

Sr. No.	**Name of Book/Authors/Publisher**	**Year of Publication/ Reprint**
1.	Gene F. Frankline, J. David Powell and Abbas Emami-Naeini, Feedback Control of Dynamical Systems. Pearson	2019

Program Elective-II

Course Name	**:**	**Renewable Energy Systems**
Course Code	**:**	**EER1251**
Credits	**:**	**3**
L T P	**:**	**3-0-0**
Course Objectives:		
In this course the students shall be 1. Made conversant with the non-conventional energy systems such as solar energy, wind energy, direct energy conversion, energy from biomass, hydro energy (micro/mini hydro plants). 2. Expected to design and analyze the non-conventional energy systems.		

Total No. of Lectures-42

Lecture wise breakup		Number of Lectures
1.	**Introduction** Introduction to Energy Sources: Energy sources and their availability, Non-renewable reserves and resources; renewable resources, Transformation of Energy.	05
2.	**Solar Energy** Solar processes and spectral composition of solar radiation; Radiation flux at the Earth s surface. Solar collectors. Types and performance characteristics. solar energy storage. b) Application of solar energy: Solar thermal electric conversion, Thermal electric conversion systems, solar electric power generation, solar Photo-Voltaic, solar cell principle, semiconductor junction, conversion efficiency and power output, Basic photovoltaic system for power generation.	10
3.	**Wind Energy** Wind energy conversion; efficiency limit for wind energy conversion, types of converters, aerodynamics of wind rotors, power ~ speed and torque ~ speed characteristics of wind turbines, wind turbine control systems; conversion to electrical power: induction and synchronous generators, grid connected and self-excited induction generator operation, constant voltage and constant frequency generation with power electronic control, single and double output systems, reactive power compensation; Characteristics of wind power plant. Applications	10
4.	**Fuel cell:** Principle of operation of an acidic , alkaline and microbial fuel cell, energy output of a fuel cell, efficiency and emf of a fuel cell, operating characteristics and thermal efficiency of fuel cell	06
4.	**Biomass Energy:** Introduction to Biomass Energy Conversion, biomass gasification, biogas conversion, energy recovery form urban, industrial waste and landfills	06
5.	**Hydro Energy:** Electricity generation and Water pumping, Micro/Mini hydropower systems, Water pumping and conversion to electricity	05

Course Outcomes: The students are able to	
CO1	Design and analyze the solar thermal energy conversion system, solar PV system
CO2	Design and analyze wind energy conversion system and its impact on grid integration
CO3	Fuel cell technology and state of art fuel cells and its application in research area.
CO4	Investigate the energy recovery from different biomass waste and electricity generation from micro/mini hydropower system.

Text Books:	
1.	D. P. Kothari, K. C. Singal, R. Ranjan, Renewable Energy Sources and Emerging Technologies, Prentice Hall of India, New Delhi, 2008.

Reference Books:	
1.	S. N. Bhadra, D. Kastha, S. Banerjee, Wind Electrical Systems, Oxford Univ. Press, New Delhi, 2005
2.	S. A. Abbasi, N. Abbasi, Renewable Energy Sources and Their Environmental

Course Name	**:**	**Power System Voltage Stability**
Course Code	**:**	**EER1252**
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

The students are expected to learn the concepts of
1. Electric power systems, voltage stability, reactive power compensation and control of transmission system, electrical loads, generation characteristics,
2. Voltage stability with HVDC links and voltage stability of a large system.

Total No. of Lectures-42

Lecture wise breakup		Number of Lectures
1.	**Review of Electric Power Systems:** Brief survey of Power System Analysis and operation, Active power & Reactive power. Transmission using Elementary models, Difficulties with reactive power transmission SCC, SCR & Voltage regulation.	04
2.	**Voltage Stability:** Voltage stability, voltage collapse, Voltage Security Time frames for Voltage Instability Mechanisms, Relation of Voltage Stability to Rotor Angle Stability, Voltage Instability in Mature Power Systems, P-V curves, V-Q curves, Graphical Explanation of Long-term Voltage stability.	08
3.	**Reactive Power Compensation and Control of Transmission System:** Transmission system characteristics, Series Capacitors, shunt capacitors and Shunt Reactors, SVS, Comparison between Series and Shunt Compensation Synchronous condensers, Transmission Network LTC transformers.	08
4.	**Electrical Loads:** Static and dynamic characteristics of Load components, Reactive compensation of Loads, LTC transformers and distribution Voltage Regulators.	04
5.	**Generation Characteristics:** Generator Reactive power capability, generator control and protection, system response to power impacts, power plant response, AGC.	06
6.	**Voltage Stability with HVDC links:** Basic Equations for HVDC, HVDC operation, Voltage Collapse, Voltage Stability concepts based on Short Circuit ratio, Power System dynamic performance.	06
7.	**Voltage Stability of a Large System:** Simulation of Equivalent Systems, Load modeling and testing, Dynamic performance including under voltage load shedding, automatic control of mechanically switched capacitors, Mitigation of voltage instability.	06

Course Outcomes: The students are able to

CO1	Explain the concepts of electric power systems, voltage stability
CO2	Investigate reactive power compensation and control of transmission system
CO3	Model electrical loads, generation characteristics and voltage stability with HVDC links
CO4	Investigate voltage stability of a large system.

Text Books:

1.	C.W. Taylor, Power System Voltage Stability, MGH-1994

Reference Books:

1.	K.R. Padiyar , Power System Dynamics Stability and Control' –B.S. Publisher-2004
2.	P. Kundur , Power System Stability and Control' –, MGH- 1994
3.	Pertinent IEEE papers.

Course Name	**:**	**Energy Management and Energy Audit**
Course Code	**:**	**EER1253**
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives: The students are expected to learn

1. The fundamentals of energy management, strategies and planning, energy conservation and recycling
2. Energy monitoring and targeting, material and energy balance.

Total No. of Lectures-42

Lecture wise breakup		Number of Lectures
1.	**Energy Scenario**: Primary energy resources, Commercial and Non-commercial energy, commercial energy production, final energy consumption, energy needs of growing economy, long term energy scenario, energy pricing, energy sector reforms, energy and environment.	06
2.	**Energy management**: Definition, significance and objectives of energy management, principle of energy management, sectors of supply side management, Energy and economy, electricity tariff, load management and maximum demand control, power factor improvement, selection and location of capacitors, optimizing the input energy requirements, fuel and energy substitution	07
3.	**Energy strategies and energy planning**: Energy Action Planning: Key elements, force field analysis, Energy policy purpose, Energy planning flow for supply side, essential data for supply side energy planning, roles and responsibilities of energy manager, Energy Audit: Definition, need of energy audit, types of energy audit, intermediate and comprehensive energy audit, end use of energy consumption profile, procedure of energy auditing, site testing and measurement. Energy security, bench marking, energy performance, matching energy use to requirement, maximizing system efficiencies, energy audit instruments, Energy Conservation Act-2001	08
4.	**Energy Conservation and Recycling**: Energy conservation and its importance, listing of energy conservation opportunities (ECOs), Electrical ECOs, ECOs in process industry, small industries building and shopping complexes, waste management, Recycling of discarded materials and energy recycling	07
5.	**Energy Monitoring and Targeting**: Defining monitoring and targeting, elements of monitoring and targeting, data and information-analysis, On line energy monitoring: Various aspects and techniques of on-line energy monitoring,	07
6.	**Material and Energy balance**: Facility as an energy system, methods for preparing process flow, material and energy balance diagrams. Financial analysis techniques-simple payback period, return on investment, net present value, internal rate of return, cash flows, risk and sensitivity analysis, financing options, energy performance contracts.	07

Course Outcomes: The students are able to

CO1	Apply the fundamentals of energy management, strategies and planning,
CO2	Apply energy conservation and recycling in buildings
CO3	Investigate energy monitoring and targeting,
CO4	Apply material and energy balance and also capable of performing energy audit in the real buildings

Text Books:

1.	S.C. Tripathy, Electrical Energy utilization and energy conversion –, Tata Mc-GrawHill -2003
2.	S.B.Pandya, Conventional energy technology –, Tata Mc-GrawHill -2003

Reference Books:

1.	Andre Gardel, Energy –Economy and prospective –Pergmon Press-2005
2.	V.A.Venikov, E.V. Putiatin , Mir, Introduction to energy technologies –Moskow -2006

3.	I.M.Campbell, Energy and Atmosphere, Wiley New York -2000
4.	Skortzki and Vopat - Power station engineering and economy-, Tata Mc-GrawHill -2003

Course Name	**:**	**Power Quality**
Course Code	**:**	**EER1254**
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

At the end of this course, the students should be able to
1. apply power electronic convertors for compensation in transmission lines and non-linear loads
2. apply power electronic convertors for harmonic reduction

Total No. of Lectures: 42

	Lecture Wise Breakup	Number of Lectures
1	**Harmonic Producing Loads, Mitigation and Power Supplies** Compensation of arc furnace and traction loads. Microwave ovens, light and temperature controllers, power supplies for appliances such as camera, X-Ray equipments. Power supplies in Telecommunication systems, High frequency induction heating, Dielectric heating, Power supplies in automobiles.	8
2	**Power Definitions and Instantaneous Reactive Power Theory** Concepts and Evolution of Electric Power Theory, Electric Power Definitions, Instantaneous Power Theory: Basis of the *pq* Theory, Clarke Transformation, *pq* theory application to 3φ-3 wire and 3φ-4 wire systems, Modified *pq* theory, Instantaneous *abc* theory. Comparison of *pq* theory and Instantaneous *abc* theory. Synchronous Reference Frame Theory and applications.	10
3	**Power Electronic Converter Harmonics and Multipulse Methods** Concepts of non-linear loads and electric power conditioning, Types of Power Sources, Power Electronic Converter Harmonics. Multi pulse methods for harmonic elimination: delta/wye, delta zigzag/Fork, Delta Polygon, Delta/delta/Double Polygon, Delta/Hexagon. Auto Wound Transformers, Interphase and Current Balancing Transformers. Calculation of Harmonics, Harmonic Standards.	12
4	**Active Power Line Conditioners** Passive filters and limitations, active filters for harmonic and reactive power compensation in two wire, three wire and four wire ac systems, Shunt Active Filter, Hybrid and Series Active Filters, Combined Series and Shunt Power Conditioners (UPFC, UPQC, UPLC). Case studies on microcomputer and DSP control in active filters and power supplies.	12

Course Outcomes: By the end of this course, the students will be able to

CO1	Realize the concepts of various transmission system compensators
CO2	Design power electronic convertors for compensation in transmission lines
CO3	Realize the concepts of non-linear loads and electric power conditioning
CO4	Design power electronic convertors for harmonic compensation to improve power quality

Suggested Books:

Sr. No.	Name of Book/Authors/Publisher	Year of Publication/ Reprint
1.	Derek A Paice, " Power Electronic Converter Harmonics (Multipulse methods for Clean Power)" IEEE Press	1995
2.	H Akagi, E.H. Watanabe and M Aredes, "Instantaneous power Theory and applications to Power Conditioning", IEEE Press, John Wiley and sons Incorporate.	2007
3.	J Arrilaga and N.R Watson, "Power System Harmonics", John Wiley and Sons Ltd.	2003
4.	A.E.Emanuel, "Power Definitions and the Physical Mechanism of Power Flow", IEEE Press, John Wiley and sons Ltd.	2010

Course Name	**:**	**Digital Signal Processing and Applications**
Course Code	**:**	**EER1255**
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:
In this course the students shall be expected to 1. Use digital signal processing for various process controls. **2.** Learn thoroughly signal and signal processing, time domain representation, transformation, filtered design etc.

Total No. of Lectures-42

Lecture wise breakup		**Number of Lectures**
1.	**Signal & Signal Processing:** classification of signals, typical signal processing operations, typical signal processing applications, why digital signal processing	03
2.	**Time Domain Representation of Signals & Systems**: Discrete- time signals, operations on sequences, the sampling process, discrete-time systems, time-domain characters tics of LTI discrete-time systems, state space representation of LTI discrete time systems.	06
3.	**Transformations:** Domain representation of signals: the discrete-time Fourier transform, discrete Fourier transform, computation of the DFT of real sequences, linear convolution using the DFT, the z-transform, the inverse z- transform	08
4.	**Time Domain Representation of LTI systems:** the frequency response, the transfer function. , Digital two-pairs stability test.	05
5.	**Digital processing of continuous time-signals:** sampling of continuous time signals, analysis filter design, anti- aliasing filter design, reconstruction filter design**.**	05
6.	**Digital Filter Structures**: block diagram representation, signal flow graph representation, equivalent structures, Basic FIR digital filter structures, Basic IIR filters structures, all pass filters, tunable structures**.**	08
7.	**Digital Filter Design**: preliminary conditions, impulse invariance method of IIR filter design, bilinear transform method of IIR filter design, design of filter IIR notch filters, FIR filter design based on truncated Fourier series, FIR filter design based on frequency sampling approach, computer-aided design of digital filters.	07

Course Outcomes: By the end of this course, the students will be able to	
CO1	Represent signal and system in time domain
CO2	Transform signal from one domain to another
CO3	Digital signal processing for various process controls
CO4	Design filtered for their projects and research applications.

Text Books:	
1.	Mitra, Sanjit .k, Digital Signal Processing, Tata-McGraw-hill edition- 2006

Reference Books:	
1.	Antoniou, A., Digital Filters: Analysis & Design McGraw –hill Book company-2006.
2.	Sterms, S.D., Digital signal Processing. Englewood cliffs, N.J.: Prentice-hall Inc- 2016

Course Name	**:**	**Grid Integration of Electric Vehicles**
Course Code	**:**	**EER1256**
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

At the end of this course the students should be able to
1. Understand the EV technologies
2. EV impact on grid integration, coordination, framework and business models.

Total No. of Lectures-42

	Lecture Wise Breakup	**Number of Lectures**
1	Electric vehicles technologies, International and national scenario on EV penetration, plug in electric vehicle system, Opportunities and Challenges in Electric Vehicle Fleet Charging Management, Environmental Impacts of the EV Batteries Recycling and Disposal.	08
2	Coordinated Operation of Electric Vehicle Charging and Renewable Power Generation Integrated in Micro grid.	08
3	Energy Storage Sizing for Plug-in Electric Vehicle Charging Stations, Economic Placement of EV Charging Stations within Urban Areas	08
4	Impacts of Large-Scale Deployment of Electric Vehicles in the Electric Power System Regulatory, Effects of EV penetration on voltage unbalance, Electric vehicles for Ancillary services in smart grid	08
5	Framework and Business Models Integrating EVs in Power Systems, Design and Operation of a low-cost EV Integrated Microgrid, Day Ahead Market Energy bidding for Smart Microgrids using AI techniques	10

Course Outcomes: By the end of this course, the students will be able to

CO1	Understand EV technologies and its impact on power system
CO2	Design Optimal charging station placement
CO3	Analyse operation of microgrid with EV integration
CO4	Framework and Business Models Integrating EVs

Text/Reference Books

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	Mohammad Saad Alam, Mahesh Krishnamurthy Electric Vehicle Integration in a Smart Microgrid Environment, CRC press	2021
2	Sumedha Rajakaruna, Farhad Shahnia, Arindam Ghosh, Plug in electric vehicles in Smart Grids integration techniques, Springer	2015
3	James Larminie, John Lowry, “Electric Vehicle Technology Explained”, Wiley.	2003

Course Name	**:**	**Optimization Techniques in Electrical Engineering**
Course Code	**:**	**EER1257**
Credits	**:**	**03**
L T P	**:**	**3-0-0**

Course Objectives: At the end of the course, the student should be able to:
1. Learn the basic concepts of different types of optimization.
2. Understand their applications in electrical engineering.
3. Implement the various artificial intelligence and evolutionary based optimizations.

Total No. of Lectures: 42

	Lecture Wise Breakup	**Number of Lectures**
1.	**Introduction** Need of optimization in electrical engineering with real world examples.	02
2.	**Linear Algebra Review** Directional Derivative, gradient, Hessian, level set, matrix diagonalization, vector space, eigen values, eigen vectors.	05
3.	**Set Constrained Optimization** Iterative search, linear square optimization, Newton method, Steepest descent and unconstrained optimization.	08
4.	**Convex Programming** Convex programming, Convexity, CVX, Geometric programming, Quasi-convex.	05
5.	**Duality** Duality, Dual decomposition, KKT conditions, Lagrangian algorithm, Sensitivity analysis.	05
6.	**LMI-Based Optimization** Linear matrix inequalities (LMI), Robust optimization, Optimal H_∞ control, Multi-objective optimization, Performance index, Non-convex optimization.	05
7.	**Artificial Intelligence and Evolutionary Algorithms-Based Optimization** Artificial intelligence Evolutionary algorithm, Artificial neural network, Particle swarm optimization, Genetic algorithm, Search methods, Gradient-based optimization, Multi-objective optimization, Pareto-optimal solution, Fitness function, Learning algorithm, Backpropagation.	12

Course Outcomes: By the end of this course, the student will be able to:

CO1	Apply the concepts of fundamentals of optimization.
CO2	Apply the concepts of set constrained optimization.
CO3	Apply the concepts of convex optimization and duality.
CO4	Implement and analyze the LMI based optimization.
CO5	Implement and analyze the artificial intelligence and various evolutionary algorithms.

Text Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	Mohammad Fathi and Hassan Bevrani, Optimization in Electrical Engineering, Springer.	2019
2	A. Beck, Introduction to Nonlinear Optimization: Theory, Algorithms, and Applications with MATLAB (SIAM-Society for Industrial and Applied Mathematics, Philadelphia, 2014)	2014
3	J. Nocedal, S. Wright, Numerical Optimization, Springer.	2006

Reference Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	E.K.P. Chong, S.H. Zak, An Introduction to Optimization (Wiley, Hoboken, 2013)	2013

Course Name	:	**System Dynamics**
Course Code	:	**EER1258**
Credits	:	**3**
L T P	:	**3-0-0**

Course Objectives:

The students are expected to:

1. Learn the concepts of system dynamics and cybernetics, model classifications
2. Understand the principles formulation of system dynamic models, building blocks and feedback loops.
3. Understand the non-linearity, casual loop diagram, generic structures, transferability of structures and dynamics of energy systems.

Total No. of Lectures: 42

Lecture Wise Breakup		**Number of Lectures**
1.	**Basics** General systems theory, system, system dynamics, relationship between system Dynamics and cybernetics. System dynamics as an approach to understand the behaviour of complex systems over time.	04
2.	**Models** Classification of Models, Abstract, physical, Static ,Dynamic, linear nonlinear, stable, unstable, steady state ,transient, open, closed, models in physical sciences engineering and social sciences. Models for controlled experiments, mechanizing the model, scope of models, objectives in using mathematical models, sources of information for constructing models.	04
3.	**Principles** Formulation of dynamic system models, time relationship, amplification, information distortion, correspondence of models and real system variables	04
4.	**Building Blocks** Basic concepts behind the study of complex systems. Examining the patterns of behaviour that real-world systems exhibit, understanding the basis of the structure that causes such patterns to emerge.	04
5.	**Processes** Feedback loops, Rate processes- stock and flows, levels and rates, exercises on graphical integration.	02
6.	**Importance of Parameters** Importance of Non-linearity, delay, initial conditions, Dimensional consistency.	03
7.	**Loop Diagrams** Causal loop diagrams, Reinforcing and balancing loops, positive and negative feedback, conceptualization exercises, loop polarity and shift in loop dominance.	03
8.	**Model Formulations** Model formulation, rate equations, auxiliary equation, table function, Levels, delays representation of decision process	03
9.	**Nature of loops** Generic structures, S shaped growth, unexpected behaviour of Ist order, 2nd order, 3rd order, and 4th order loops, Exponential, oscillating systems.	03
10.	**Structures** Transferability of structures, Archetypes	03
11.	**Modeling** Group modelling, system thinking as paradigm, necessity and benefit of system dynamics, exercise in group modelling.	03
12.	**Dynamics of Energy Systems** Understanding the dynamics of Energy (World and India) Systems	03
13.	**Meta System Engineering** System schema, world schema, pattern, form, Holon, system domains, Emergent properties, domain engineering, world engineering, whole system design.	03

Course Outcomes: By the end of this course, the student will be able to:	
CO1	Apply the concepts of system dynamics and cybernetics and model classifications.
CO2	Implement the principles formulation of system dynamic models, building blocks, feedback loops, non-

	Linearity and casual loop diagram.
CO3	Analyze the generic structures and transferability of structures.
CO4	Implement the concepts of nature of loops and modeling.
CO5	Apply the concepts of dynamics of energy systems and meta system engineering.

Text Books:		
Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	Introduction to System Dynamics by Michael J. radzicki and Robert A. Taylor.	1997
2	Introduction to Systems Science, Jay Forrester	1997

Reference Books:		
Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	Fifth discipline- Peter Senge	1997

Course Name	**:**	**Fractional Order Systems: Modeling and Control Applications**
Course Code	**:**	**EER1259**
Credits	**:**	**03**
L T P	**:**	**3-0-0**

Course Objectives: At the end of this course, the students shall be able to:
1. Understand the concepts of fractional order calculus 2. Learn the several fractional order controls for various kinds of systems 3. Learn the implementation of fractional order control techniques

Total No. of Lectures: 42

Lecture Wise Breakup		**Number of Lectures**
1.	**Introduction to Fractional Calculus** Fractional Calculus, Geometrical Meaning of Fractional Integration and Differentiation, A Physical Interpretation of Fractional Differintegrals, Laplace Transform of Fractional Differintegrals, Frequency Domain Interpretation, the Power Function.	07
2.	**Fractional Systems for Control** Fractional Control, The Two Parameters Mittag-Leffler Function, Fractional LTI Systems, Commensurate Fractional LTI Systems, modes, stability.	08
3.	**Fractional-Order Proportional-Integral-Derivative Controllers** FOPID Controller Structure, FOPID Tuning, Optimal Tuning Rules for Self-Regulating Processes, Optimal Tuning Rules for Integral Processes, Optimal Tuning Rules for Unstable Processes, FOPID Controller Additional Functionalities.	08
4.	**H∞ Control of Fractional Systems** Factorization of Fractional Transfer Functions, Stabilizing Controllers, The Standard H∞ Control Problem, The Model-Matching Problem, H∞ Optimization-Based FOPID Design.	11
5.	**Advanced Fractional Order Control Techniques** Fractional order sliding mode control and backstepping method, examples.	08

Course Outcomes: By the end of this course, the student will be able to:	
CO1	Apply the concepts of fundamentals of fractional order calculus in modeling the systems.
CO2	Apply the concepts of fractional order stability.
CO3	Design FOPID control for fractional systems.
CO4	Design H∞ control for fractional systems.
CO5	Design and analyze the advanced fractional order control techniques for various practical problems.

Text Books:		
Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	Padula, F. and Visioli, A., Advances in robust fractional control : Springer International Publishing.	2015
2	Caponetto, Riccardo. Fractional order systems: modeling and control applications. Vol. 72. World Scientific, 2010.	2010

Reference Books:		
Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	Petráš, Ivo. Fractional-order nonlinear systems: modeling, analysis and simulation. Springer Science & Business Media.	2011
2	Luo, Ying, and Yang Chen. Fractional order motion controls. John Wiley & Sons.	2012

Course Name	**:**	**Electric Drives for EV Applications**
Course Code	**:**	**EER1260**
Credits	**:**	**3**
LTP	**:**	**3-0-0**

Course Objectives:

At the end of this course, the students should be able to
1. Learn basic concepts of electric vehicle technology
2. Learn and compare various types of electric drives used in electric vehicles technology

Total No. of Lecture - 42

Lecture Wise Breakup		**Number of Lecture**
1.	**Introduction to Electric Vehicles (EV)** Pure electric vehicle, hybrid electric vehicle, gridable hybrid electric vehicle and fuel cell electric vehicle. EV Technologies: Motor drive technology, energy source technology, battery charging technology, vehicle to grid technology	4
2.	**DC Motor Drives for Electric Vehicles (EV)** Structure and modeling of dc machine, hard switched and soft switched dc-dc convertor topologies for EV applications. speed control and regenerative braking. Design criteria for dc motor drives for EV. Design and application examples of DC motor drive in EV. Drawbacks of dc motor drive technology for EV.	9
3.	**Induction Motor Drives for Electric Vehicles (EV)** System configurations. Structure, principle and modeling of Induction machine. PWM and soft switching inverters for induction motor drives. Comparative analysis of VVVF, FOC and DTC control of induction motor for EV applications. Design criteria for induction motor drives for EV. Design and application examples of induction motor drive in EV.	9
4.	**Permanent Magnet Brushless Motor Drives for Electric Vehicles (EV)** PM materials and system configurations. Structure, principle and modeling of PM brushless machines. Inverters requirements and switching scheme for brushless AC and DC operation. PM brushless motor control (PMSM and PMBLDC). Design criteria for PM brushless drives for EV. Design and application examples of PM brushless drive in EV.	10
5.	**Switched Reluctance (SR) Motor Drives for Electric Vehicles (EV)** System configurations. Structure, principle and modeling of SR machines. power convertors for SR motor drives and their comparative analysis. Speed control, torque ripple minimization and position sensorless control of SR motors. Design criteria for SR motor drives for EV. Design and application examples of SR motor drive in EV.	10

Course Outcomes: By the end of this course, the students will be able to

CO1	Realize the basic concepts of electric vehicle technologies
CO2	Analyze and compare different types of electric drives used in EV technology
CO3	Design appropriate electric drive for a specific EV application

Suggested Books:

Sr. No.	**Name of Book/Authors/Publisher**	**Year of Publication/ Reprint**
1.	K T Chau, Electric Vehicle Machines And Drives, Design, Analysis And Application, John Wiley And Sons, ISBN 978-1-118-75252-4	2015

Course Name	**:**	**Power Electronics for Renewable Energy Systems**
Course Code	**:**	**EER1261**
Credits	**:**	**3**
LTP	**:**	**3-0-0**

Course Objectives:

At the end of this course, the students should be able to
1. Understand and analyze various power electronic convertors used in Photo-voltaic systems
2. Understand and analyze various power electronic convertors used in wind energy systems

Total No. of Lecture - 42

Lecture Wise Breakup		**Number of Lecture**
1.	**Power Electronics Applications in Photo-voltaic(PV) Systems** PV Modeling: Electrical characteristics, equivalent circuit, lambert w function for modeling a PV field. Field maximum power point tracking (FMPPT): P&O method, P&O with adaptive step sixe and parabolic approximation, incremental conductance and advanced methods. MPPT efficiency. P&O applied to closed loop switching converters. Instability of current based MPPT, sliding mode control and design with voltage controller. Methods to reduce noise sources. Distributed MPPT (DMPPT) for photovoltaic arrays through micro inverters and dc-dc converters. DC analysis of PV array with DMPPT. Self-controlled PV module (SCPVM). I-V and P-V characteristics of buck and buck boost based SCPVM. efficiency power converters for PV MPPT applications. Single and three phase photovoltaic systems: structures topology and control, modulation strategies, grid synchronization, grid integration functions.	21
2.	**Power Electronics Applications in Wind Energy(WE) Systems** Generator and turbine selection for small scale wind energy systems. SEIG and PMSG for small scale wind energy systems, Grid-Tied Small Wind Turbine Systems, Magnus Turbine–Based Wind Energy System. Power Electronics and Controls for Large Wind Turbines and Wind Farms: two level and multilevel convertor topologies, Cascaded H-Bridge Converter with Medium-Frequency Transformers, Modular Multilevel Converter. Electric Generators and their Control for Large Wind Turbines, topology and circuit models and control strategy for doubly fed induction generator (DFIG), Cage rotor induction generator (CRIG), Permanent magnet synchronous generator (PMSG) and dc excited synchronous generator (DCE-SG)	21

Course Outcomes: By the end of this course, the students will be able to

CO1	Analyze various mathematical aspects of power electronic convertors used in PV applications
CO2	Analyze various circuit aspects of power electronic convertors used in PV applications
CO3	Analyze various mathematical aspects of power electronic convertors used in Wind Energy conversion applications
CO4	Analyze various circuit aspects of power electronic convertors used in Wind Energy conversion applications

Suggested Books:

Sr. No.	**Name of Book/Authors/Publisher**	**Year of Publication/ Reprint**
1.	Frede Blaabjerg & Dan M Ionel, Renewable Energy Devices and Systems with Simulations in MATLAB® and ANSYS®, Taylor and Francis, 13: 978-1-4987-6582-4	2017
2.	Nicola Femia, Power Electronics and Control Techniques for Maximum Energy Harvesting in Photovoltaic Systems, CRC Press Taylor and Francis, ISBN-13- 978-1-4665-0691-6	2012

Course Name	**:**	**Advanced Power Convertors**
Course Code	**:**	**EER1262**
Credits	**:**	**3**
LTP	**:**	**3-0-0**
Course Objectives:		
At the end of this course, the students should be able to 1. Learn the modeling and control of advanced power electronic converters 2. Design controllers for impedance source power electronic converters		

Total No. of Lecture - 42

Lecture Wise Breakup		**Number of Lecture**
1	**PWM Rectifiers** Ideal rectifier, realization of near ideal rectifier, control of the current waveform: average current control, current programmed control, critical conduction mode, hysteretic control and nonlinear carrier control. Dynamical modelling and design of current and voltage loops of active rectifiers.	20
2	**Impedance Source Power Electronic Converters** Voltage-Fed Z-Source/Quasi-Z-Source Inverters: steady state and dynamic model. Current-Fed Z-Source/ Quasi-Z-Source Inverters: Modulation modelling and control. Design of passive components and DCM mode. Modulation methods: sinewave pwm (simple boost, maximum boost, maximum constant boost control), space vector modulations, pulse width amplitude modulation. Comparison of modulation methods. Control of shoot through duty cycle: single loop methods, double loop methods. Conventional regulators and advanced control methods.	22

Course Outcomes: By the end of this course, the students will be able to	
CO1	Model and design controllers for active rectifiers
CO2	Realize the modulation techniques of impedance source power electronic converters
CO3	Model and design controllers for impedance source power electronic converters

Suggested Books:

Sr. No.	**Name of Book/Authors/Publisher**	**Year of Publication/ Reprint**
1.	Liu Yushan, Impedance Source Power Electronic Converters, John Wiley ISBN 9781119037071	2016
2.	Robert W. Erickson & Dragan Maksimovic, Fundamentals of Power Electronics, second edition, springer. ISBN 9788181283634	2014

Course Name	**:**	**Power Quality**
Course Code	**:**	**EER1263**
Credits	**:**	**3**
LTP	**:**	**3-0-0**

Course Objectives:

At the end of this course, the students will be able to
1. Have in depth knowledge of various aspects of power quality issues and their mitigation methods
2. Design power electronic converters for harmonic elimination

Total No. of Lecture - 42

Lecture Wise Breakup		**Number of Lecture**
1.	**Introduction to Power Quality** Various types of power quality issues: frequency fluctuation, slow voltage variation, voltage fluctuation, voltage sag or dip and shot interruptions, voltage imbalance, harmonic voltage. Overview of Active power line conditioners. Electrical Power Terms in the IEEE Std 1459 Framework. IEEE working group discussions on non-sinusoidal situations.	4
2.	**Power Definitions and Instantaneous Reactive Power Theory** Concepts and Evolution of Electric Power Theory, Electric Power Definitions, Instantaneous Power Theory: Basis of the *pq* Theory, Clarke Transformation, *pq* theory application to 3φ-3 wire and 3φ-4 wire systems, Modified *pq* theory, Instantaneous *abc* theory. Comparison of *pq* theory and Instantaneous *abc* theory. Synchronous Reference Frame Theory and applications.	10
3.	**Power Electronic Converter Harmonics and Multipulse Methods** Power Electronic Converter Harmonics. Multi pulse methods for harmonic elimination: delta/wye, delta zigzag/Fork, Delta Polygon, Delta/delta/Double Polygon, Delta/Hexagon. Auto Wound Transformers, Interphase and Current Balancing Transformers.	8
4.	**Active Power Line Conditioners** Fundamentals of shunt active power filters (APF), shunt APF structures and compensation strategies. Design considerations of shunt APF. Fundamentals of series active power filters. State space models of series APF and different control strategies. Hybrid active power filters: series active shunt passive and shunt active shunt passive. Comparison of hybrid active filters with control strategies. Combined shunt and series active power filters: unified power quality conditioners (UPQC), control strategy of UPQC and passive parameters design. Unified power line conditioners (UPLC).	12
5.	Distributed generation impact in power quality, distribution line compensation: instantaneous unity power factor control, positive sequence control.	08

Course Outcomes: By the end of this course, the students will be able to	
CO1	Realize the Concepts and Evolution of Electric Power Theory
CO2	Identify various power quality related issues arising in power system due to different non-linear loads
CO3	Design compensators and convertors for mitigation of harmonics for different scenarios and systems

Suggested Books:

Sr. No.	**Name of Book/Authors/Publisher**	**Year of Publication/ Reprint**
1.	Patricio Salmerón Revuelta, Active Power Line Conditioners: Design, Simulation and Implementation for Improving Power Quality. Elsevier. ISBN 978-0-12-803216-9	2016
2.	Derek A Paice, “ Power Electronic Converter Harmonics (Multipulse methods for Clean Power)” IEEE Press	1995
3.	H Akagi, E.H. Watanabe and M Aredes, “Instantaneous power Theory and applications to Power Conditioning”, IEEE Press, John Wiley and sons Incorporate	2007
4.	J Arrilaga and N.R Watson, “Power System Harmonics”, John Wiley and Sons Ltd	2003
5.	A.E.Emanuel, “Power Definitions and the Physical Mechanism of Power Flow”, IEEE Press, John Wiley and sons Ltd	2010

Course Name	**:**	**Special Machine Drives**
Course Code	**:**	**EER1264**
Credits	**:**	**3**
LTP	**:**	**3-0-0**

Course Objectives:

At the end of this course, the students should be able to
1. Analyze and design controllers for special machines
2. Design power convertors for special machines drives

Total No. of Lecture - 42

Lecture Wise Breakup		Number of Lecture
1.	**Permanent Magnet Synchronous Motor (PMSM) Drives** Constructional features and types of PMSM. Vector control of PMSM. Control strategies: constant torque angle control, unity power factor control, constant mutual flux linkage control and optimum torque per ampere control. Flux weakening operation: direct and indirect flux weakening, control scheme. Design of speed controller, sensorless control. parameter sensitivity.	14
2.	**Permanent Magnet Brushless DC Motor (PMBLDC) Drives** Modelling of PMBLDC, drive scheme, dynamic simulation & commutation torque ripple in PMBLDC. Half wave PMBLDC drives: split supply convertor topology, c-dump topology and variable dc link converter topology. Sensorless control of PMBLDC motor, torque smoothing, design of speed and current controllers, parameter sensitivity.	14
3.	**Switched Reluctance Motor (SRM) Drives** SRM types, constructional features and inductance variation. Average and instantaneous torque of SRM. Power converters for SRM drives: Asymmetric converters, single switch per phase converters, c-dump converters and two stage power converters. Control principles and design of SRM drives: modelling of SRM, small signal model, current loop, speed loop, voltage and torque equations, flux linkage controller and methods for torque control.	14

Course Outcomes: By the end of this course, the students will be able to

CO1	Realize the modeling and control strategies of PMSM and PMBLDC motors
CO2	Analyze and design power convertors and controllers for PMSM and PMBLDC motors
CO3	Realize the modeling and control strategies of SRM motors
CO4	Analyze and design power convertors and controllers for SRM motors

Suggested Books:

Sr. No.	Name of Book/Authors/Publisher	Year of Publication/ Reprint
1.	R. Krishnan, Electric Motor Drives: Modeling Analysis & Control Pearson Education	2001
2.	R. Krishnan, Switched Reluctance motor drives, Modeling, Simulation, Analysis, Design, and Applications CRC press ISBN- 9781315220062	2001

Open Electives

Course Name	**:**	**Energy Management and Audit**
Course Code	**:**	**EER3001**
Credits	**:**	**3**
LTP	**:**	**3-0-0**
Course Objectives:		
At the end of this course, the students should be able to acquire the knowledge of 1. Energy management 2. Energy conservation and recycling 3. Energy monitoring and energy auditing		

Total Number of Lectures: 42

Lecture Wise Breakup		**Number of Lectures**
1.	**Energy Scenario** Commercial and non-commercial energy, primary energy resources, commercial energy production, final energy consumption, energy needs of growing economy, long term energy scenario, energy pricing, energy sector reforms, energy and environment, energy security, energy conservation and its importance, restructuring of the energy supply sector, energy strategy for the future, air pollution, climate change. Energy Conservation Act-2001 and its features.	06
2.	**Basics of Energy and its Various Forms** Electricity tariff, load management and maximum demand control. Thermal basics: fuels, thermal energy contents of fuel, temperature and pressure, heat capacity, sensible and latent heat, evaporation, condensation, steam, moist air and humidity, heat transfer, units and conversion.	07
3.	**Energy Management and Audit** Definition, energy audit, need, types of energy audit. Energy management (audit) approach understanding energy costs, benchmarking, energy performance, matching energy use to requirement, maximizing system efficiencies, optimizing the input energy requirements, fuel and energy substitution, energy audit instruments. Material and energy balance: facility as an energy system, methods for preparing process flow, material and energy balance diagrams.	06
4.	**Energy Efficiency in Electrical Systems** Electrical system: electricity billing, electrical load management and maximum demand control, power factor improvement and its benefit, selection and location of capacitors, performance assessment of PF capacitors, distribution and transformer losses. Electric motors: types, losses in induction motors, motor efficiency, factors affecting motor performance, rewinding and motor replacement issues, energy saving opportunities with energy efficient motors.	07
5.	**Energy Efficiency in Industrial Systems** Compressed air system: types of air compressors, compressor efficiency, efficient compressor operation, compressed air system components, capacity assessment, leakage test, factors affecting the performance and savings opportunities in HVAC. Fans and blowers: types, performance evaluation, efficient system operation, flow control strategies and energy conservation opportunities. Pumps and pumping system: types, performance evaluation, efficient system operation, flow control strategies and energy conservation opportunities. Cooling tower: types and performance evaluation, efficient system operation, flow control strategies and energy saving opportunities, assessment of cooling towers.	08
6.	**Energy Efficient Technologies in Electrical Systems** Maximum demand controllers, automatic power factor controllers, energy efficient motors, soft starters with energy saver, variable speed drives, energy efficient transformers, electronic ballast, occupancy sensors, energy efficient lighting controls, energy saving potential of each technology.	08

Course Outcomes: By the end of this course, the students will be able to	
CO1	Apply the fundamental knowledge of energy management.

CO2	Perform energy audit & management
CO3	Apply concept of strategies and planning for energy conservation, recycling for energy monitoring and targeting.
CO4	Perform energy audit in the day to day activities involving industries, buildings and any field of life where energy is involved.
CO5	Apply energy efficient technologies in electrical system

Suggested Books:		
Sr. No.	**Name of Book/Authors/Publisher**	**Year of Publication/ Reprint**
1.	Handbook on Energy Audit and Environment Management by Abbi, Y.P. and Jain, S, Teri Bookstore	2006
2.	Handbook of Energy Audits by Albert Thumann, Terry Niehus and W. Younger, CRC Press	2008
3.	Energy Engineering and Management by Amlan Chakrabarti, 2nd Edition, PHI Learning Pvt. Ltd.	2018
4.	Energy Management Principles: Applications, Benefits, Savings, Elsevier	2016
5.	Industrial Energy Management: Principles and Applications by Giovanni Petrecca, The Kluwer international series -207	1999
6.	Energy Management Handbook by W. C. Turner, John Wiley and sons.	2004
7.	Utilization of Electrical Energy and Conservation by S. C. Tripathy, McGraw Hill,	1991
8.	Guide books for National Certification Examination for Energy Managers and Energy Auditors by Bureau of Energy Efficiency (BEE) (4 books). Available online for download at https://beeindia.gov.in/content/energy-auditors	

Course Name	:	**Zero Energy Buildings**
Course Code	:	**EER3002**
Credits	:	**3**
L T P	:	**3-0-0**

Course Objectives:

At the end of the course the students should be able to understand
1. The fundamental concepts of high energy efficient building design
2. Passive design strategies for building
3. Technology applications in net-zero energy building

Total No. of Lectures: 42

Lecture Wise Breakup		Number of Lectures
1.	**Built Environment and Climate Change** Current energy consumption scenario in India, Need to reduce emissions. Status, challenges and opportunities, Definition of Green Building. Impact of design, construction & maintenance of buildings on our environment and natural resources. Benefits of building green. Design of buildings to use renewable energy, optimization of materials use.	08
2.	**Highly Energy-Efficient Buildings** Heat transfer processes in buildings. Thermal conductivity, resistance, transmittance, surface characteristics, surface coefficient, heat capacity, insulation, Estimation of building energy performance for heating and cooling for different climatic contexts, Identification of opportunities for reducing energy consumption.	08
3.	**Passive Design Strategies, Principles, and Techniques** Climate Issues, Thermal Comfort Requirements, Site and microclimate, Orientation, Solar Geometry/Solar Control, Window Placement, High Performance Window, Daylighting, Shading Devices, Space Arrangements, Continuous Super Insulation, Moisture Control, Air Sealing (Air-tightness), Thermal Mass, Passive Heating/Cooling, Balanced Ventilation, Heat/Energy Recovery Ventilation System (HRV/ERV), Thermal Bridging etc.,	14
4.	**Net-Zero Energy Buildings Systems, Technologies and Applications** Integrated Photovoltaic System (BIPV), Solar Thermal Collectors (STC), Building Integrated Wind Turbine (BIWT), Rooftop PV System, Ground-Mounted Solar Panels, Geothermal Heat Pumps (GHP), Combined Heat and Power (CHP) system, LED Lighting Fixtures, etc.	12

Course Outcomes: By the end of this course, the student will be able to:

CO1	Analyse thermal performance of building
CO2	Estimate heating-cooling performance of building
CO3	Passive design of building
CO4	Net-zero energy building system
CO5	Carry out the sizing of renewable energy sources needed for building.

Text/ Reference Books

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1.	Iyengar, K. Sustainable Architectural Design: An Overview, Routledge	2015
2.	Chiras, D. The Solar House: Passive Heating and Cooling. Chelsea Green Publishing.	2002
3.	Corner, D., Fillinger, J., Kwok, A. Passive House Details: Solutions for High-Performance Design, Routledge.	2017
4.	James, M. Net Zero Energy Buildings Passive House+ Renewables, Low Carbon Productions.	2015

5.	Attia, shady. Net Zero Energy Buildings (NZEB): Concepts, Frameworks and Roadmap for Project Analysis and Implementation. Butterworth-Heinemann.	2018

Course Name	**:**	**Electric Vehicles**
Course Code	**:**	**EER3003**
Credits	**:**	**3**
L T P	**:**	**2-0-2**

Course Objectives:

At the end of this course the students should be able to acquire the knowledge of
1. Electric and hybrid vehicle operation, and architectures
2. Energy storage system for Electric vehicle, energy management
3. Power convertors in electric vehicles

Total No. of Lectures: 28

Lecture Wise Breakup		**Number of Lectures**
1.	**Introduction to Electric Vehicles** Electric vehicles (EV) development, past, present and future, comparison with IC engine drive vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies, basics of vehicle performance, vehicle power source characterization, transmission characteristics. Mathematical models to describe vehicle performance, basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis.	05
2.	**Electric Propulsion Unit** Introduction to electric components used in hybrid and electric vehicles, different types of motors used in EV and their torque-speed characteristics, configuration and control of DC motor drives, configuration and control: induction motor, permanent magnet motor, switch reluctance motor drives; drive system efficiency.	06
3.	**Energy Storage in Vehicles** Introduction to energy storage requirements in hybrid and electric vehicles, storage types: battery, supercapacitor, flywheel, and fuel cell based energy storage and its analysis; hybridization of different energy storage devices.	03
4.	**Battery Chargers** Fundamentals of EV battery pack design, AC and DC Chargers, low voltage DC fast charger for electric vehicles, alternate charging sources – wireless & solar, battery management system.	04
5.	**Power Converters in Electric Drive Vehicles** Converter topologies: bidirectional DC-DC converters, bidirectional T-type converter, resonant converter, multilevel two-quadrant converter, PWM inverters.	03
6.	**Energy Management and Control 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.	04
7.	**Electric Vehicle Case Studies** Design of a battery electric vehicle (BEV), design of fuel cell electric vehicle, design of hybrid electric vehicle, design of more electric aircraft.	03

List of Experiments:		**Number of Turns**
1.	To obtain the performance of lead-acid and li-ion battery energy storage.	02
2.	To obtain the performance of supercapacitor.	01
3.	To simulate lead-acid/li-ion battery and supercapacitor hybrid energy storage system.	02
4.	To simulate the I-V characteristics of fuel cell.	01
5.	To obtain the difference in performance of AC and DC chargers.	01
6.	To simulate the DC fast chargers for electric vehicles (EV).	01
7.	To simulate the battery management system.	01
8.	To obtain the performance of bidirectional DC-DC converters.	01
9.	To simulate sine PWM inverters.	01
10.	To obtain the performance of – permanent magnet, induction and switched reluctance motors.	02
11.	To simulate the battery based EV.	01

Course Outcomes: By the end of this course, the students will be able to	
CO1	Draw inferiors from electric vehicle characteristics
CO2	Understand electric propulsion unit
CO3	Energy storage devices in electric vehicle
CO4	Power electric application in electric vehicle
CO5	Energy management in electric vehicle system

Text/Reference Books

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	Iqbal Husain, "Electric and Hybrid Vehicles: Design Fundamentals", 3rd edition CRC Press.	2021
2.	Tom Denton, "Electric and Hybrid Vehicles", Taylor & Francis.	2018
3.	Mehrdad Ehsani, Yimin Gao, Stefano Longo, Kambiz M. Ebrahimi, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles", Taylor & Francis Group, LLC.	2018
4.	John Miller, "Propulsion Systems for Hybrid Vehicles," Institute of Electrical Engineers, UK.	2004
5.	Chris Mi, M A Masrur, D W Gao, " Hybrid Electric Vehicles – Principles and applications with practical perspectives," Wiley.	2011
6.	James Larminie, John Lowry, "Electric Vehicle Technology Explained", Wiley.	2003
7.	C.M. Jefferson & R.H. Barnard, " Hybrid Vehicle Propulsion," WIT Press.	2002

Course Name	**:**	**Hydrogen Energy and Fuel Cells**
Course Code	**:**	**EER3004**
Credits	**:**	**3**
L T P	**:**	**2-0-2**

Course Objectives:

At the end of the course the students should be able to understand the fundamental concepts of
1. Hydrogen generation
2. Fuel cell technologies
3. Fuel cell energy production

Total No. of Lectures: 28

	Lecture Wise Breakup	Number of Lectures
1.	**Hydrogen Energy** Possible role of hydrogen and fuel cells, Production of Hydrogen: steam reforming, partial oxidation, dry reforming, water electrolysis: reverse fuel cell operation, biological hydrogen production: photosynthesis, issues related to scale of production: centralized hydrogen production, distributed hydrogen production,	05
2.	**Hydrogen conversion, storage, and transmission** Hydrogen uses as an energy carrier, storage medium, combustion uses, direct uses, hydrogen storage: compressed gas storage, liquid hydrogen storage, hydride storage (solid hydrogen), metal hydride, hydrogen storage in renewable energy systems, comparing storage options, hydrogen transmission: container transport, pipeline transport	08
3.	**Fuel cells technologies** Introduction and overview, operating principle, polarization curves, types of fuel cell, electrolytes used in fuel cells, low and high temperature fuel cells, proton exchange membrane, solid oxide, molten carbonate, acid and alkaline, fuel cell stacks, concept of electrochemical potential and emf, Nernst equation, thermodynamic efficiencies of fuel cell in comparison to Carnot efficiencies	08
4.	**Fuel cells systems and Implementation scenarios** Storage infrastructure, transmission infrastructure, local distribution, filling stations, safety concerns and requirements, National and international standards, cost expectations: hydrogen production costs, fuel cell costs, hydrogen storage, infrastructure costs, system costs, life cycle analysis of hydrogen production, life cycle analysis of fuel cells, life cycle comparison of conventional passenger car and passenger car with fuel cells	07

	List of Experiments	Number of Hours
1.	Modelling of Electrolyzer System	5
2.	Modelling of Proton Exchange Membrane Fuel Cell System	5
3.	Simulation of Fuel Cell Technologies	4

Course Outcomes: By the end of this course, the student will be able to:

CO1	Acquire knowledge pertaining to green hydrogen technologies
CO2	Carry out the life cycle cost analysis of long term and short term hydrogen storage system
CO3	Design the electrolyzer-fuel cell system
CO4	Simulation of electrolyzer system
CO5	Simulation of fuel cell system

Text/ Reference Books		
Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	Bent Sorensen. “Hydrogen and Fuel Cells”.	2018
2.	Larminie J., Dicks A. and McDonald M. S. Fuel cell systems explained. Vol. 2, Wiley	2003
3.	O'Hayre R. P., Cha S. W., Colella W., and Prinz F. B., Fuel cell fundamentals, John Wiley	2008

Course Name	**:**	**Neural Networks and Fuzzy Logic**
Course Code	**:**	**EER3005**
Credits	**:**	**03**
L T P	**:**	**3-0-0**

Course Objectives:

At the end of this course, the student should be able to:
1. Acquire knowledge of neural networks and fuzzy systems.
2. Understand the different structures of neural networks for different applications.
3. Learn the designing of fuzzy systems for different applications.

Total No. of Lectures – 42

Lecture wise breakup		Number of Lectures
1.	**Introduction** Biological neuron, Models of Artificial Neural Networks (ANN), Characteristics of Neural Networks, Different types of learning of neural network.	04
2.	**Fundamental Models of ANN** Mcculloch–Pitts, Hebbian, Perceptron, Delta, Owstrar, Boltzman, Adaline, Madaline: Architecture, Algorithm and Applications.	05
3.	**Feed Forward Networks** Back propagation, Radial basis function- Architecture, Algorithm and Applications.	04
4.	**Self Organizing Feature Map** Kohonen Self Organizing Maps, Learning Vector Quantization (LVQ), Max. Net, Hamming Net-Architecture, Algorithm and Applications.	04
5.	**Feedback Networks** Hopfield Net- Architecture, Training Algorithm and Application for discrete and continuous net.	03
6.	**Associative Memory Networks** Hetero, Auto and Bi-directional Associative Networks-Architecture, Algorithm and Applications.	03
7.	**Application of Neural Networks** Application of neural network in engineering areas.	03
8.	**Introduction of Fuzzy Systems** Fuzzy logic, classical sets and fuzzy sets, operations on fuzzy sets, properties of fuzzy sets, crisp and fuzzy relations, membership functions, fuzzification, defuzzification.	09
9.	**Fuzzy Rule Based System** Formation of rules, decomposition of rules, aggregation and properties of fuzzy rules, fuzzy inference system.	04
10.	**Applications of Fuzzy Logic** Fuzzy logic applications in various areas including power systems, image processing, control systems, industries etc.	03

Course Outcomes: By the end of this course, the student will be able to:

CO1	Apply the concepts of fundamentals and learning algorithms of neural network.
CO2	Design and analyze the feed forward networks and self organizing feature map.
CO3	Design and analyze feedback networks and associative memory networks.
CO4	Implement the fuzzy logic systems for different problems.
CO5	Design neural network and fuzzy system for practical problems.

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1	Fundamental of Neural Networks-Architectures, Algorithm and Applications by Laurene Fausett, Pearson,.	1993

2	Neural Networks- A comprehensive foundation by Simon Haykin, Macmillan Publishing Company, New York,.	1994
3	Neural Networks-A classroom approach by Satish Kumar, The McGraw-Hill Companies,.	2005
4	Fuzzy Logic with Engineering Applications by Timothy J. Ross Wiley Student Edition,.	2010
5	Introduction to Neural Networks using MATLAB by S.N. Sivanandam, S. Sumati and S.N. Deepa, Tata McGraw Hill,.	2006
6	Introduction to Fuzzy Logic using MATLAB by S.N. Sivanandam, S. Sumati and S.N. Deepa, Springer,.	2007

Course Name	**:**	**Intelligent Control**
Course Code	**:**	**EER3006**
Credits	**:**	**03**
L T P	**:**	**3-0-0**

Course Objectives:
The main objectives of this course are 1. To learn the basic concepts of ANN 2. To study the fuzzy logic theory 3 .To study and design the ANNs and fuzzy logic systems for practical applications

Total No. of Lectures: 42

Lecture Wise Breakup		**Number of Lectures**
1.	**Introduction** Biological neuron & their artificial models, Models of Artificial neural networks, Neural processing, Learning and adaptation, Neural network learning rules-hebbian, perception, delta, windrow-Holf learning rule. Winner Take all, outstan learning, Adalin & Madaline networks.	06
2.	**Supervised learning** Single layer networks, Perception-linear separability, Limitations, Multilayer networks back propagation, algorithm and their training limitations, applications, Feed forward networks – Radial basis function.	08
3.	**Unsupervised Winner** Hamming networks, Maxnet, counter propagation network; adaptive resonance theory, Kohem'sself organizing maps.	06
4.	**Associative memories** Auto Associative memories and Bidirectional memories**.**	03
5.	**Special Networks** Cognitron, Neocognition, statistical methods-Boltzmann machine, Cauchy's machine, simulated annealing.	06
6.	**Optimization** Hopfield Network – TSP, A/D converter.	03
7.	**Fuzzy Logic** Fuzzy sets & membership ,Operation & properties of classical sets, Fuzzy set operation and properties of fuzzy sets, Features of MF, standard forms and boundaries, Fuzzification, membership value of assignments, fuzzy sets and fuzzy relations, defuzzification methods.Fuzzy Rule Based Systems, applications of neural networks and fuzzy controllers in Electrical Engineering.	10

Course Outcomes: By the end of this course, the student will be able to:	
CO1	Apply the concepts of neural network learning rules.
CO2	Apply the concepts of ANN neural networks such as backpropagation and radial basis feedforward network.
CO3	Implement the counter-propagation network, adaptive resonance network, Kohnen self organizing maps and memories.
CO4	To apply concepts of fuzzy control.
CO5	To apply control applications of these to engineering problems.

Text Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	Introduction to Artificial neural networks, J.M.Jurada, Jaico Publishers Mumbai.	1997
2.	Fuzzy logic with Engineering Applications by Timothy J. Ross – McGraw Hill, Inc.	1997

3.	Simon Haykin, Neural Networks – A Comprehensive Foundation, Macmillan Publishing Co., New York.	1994
4.	Neural Network, Fuzzy logic and Genetic Algorithms Synthesis and applications – S. Rajasekaran & G.A. VijaylakshmiPai	2003

Reference Books:		
Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	Understanding Neural Networks and Fuzzy logic by S.V.KartaloPoulos – PHI.	1997
2	Fuzzy Sets & Fuzzy logic Theory & applications by George J. Klir/Bo Yaun-PHI.	1996
3	Introductory to Neural Networks using Matlab 6.0 by S.N.Sivanandan and S.N.Deepa, TMH.	2006
4	Neural computing: Theory & Practice by Philip D. Wasserman Auza Research Inc. Van Nostrand.	1989

Course Name	**:**	**Renewable Energy Systems**
Course Code	**:**	**EER3007**
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives: In this course the students shall be

1. Made conversant with the non-conventional energy systems such as solar energy, wind energy, direct energy conversion, energy from biomass, hydro energy (micro/mini hydro plants).
2. Expected to design and analyze the non-conventional energy systems.

Total No. of Lectures-42

Lecture wise breakup		Number of Lectures
1.	**Introduction** Introduction to Energy Sources: Energy sources and their availability, Non-renewable reserves and resources; renewable resources, Transformation of Energy.	05
2.	**Solar Energy** Solar processes and spectral composition of solar radiation; Radiation flux at the Earth s surface. Solar collectors. Types and performance characteristics. solar energy storage. b) Application of solar energy: Solar thermal electric conversion, Thermal electric conversion systems, solar electric power generation, solar Photo-Voltaic, solar cell principle, semiconductor junction, conversion efficiency and power output, Basic photovoltaic system for power generation.	10
3.	**Wind Energy** Wind energy conversion; efficiency limit for wind energy conversion, types of converters, aerodynamics of wind rotors, power ~ speed and torque ~ speed characteristics of wind turbines, wind turbine control systems; conversion to electrical power: induction and synchronous generators, grid connected and self-excited induction generator operation, constant voltage and constant frequency generation with power electronic control, single and double output systems, reactive power compensation; Characteristics of wind power plant. Applications	10
4.	**Fuel cell:** Principle of operation of an acidic , alkaline and microbial fuel cell, energy output of a fuel cell, efficiency and emf of a fuel cell, operating characteristics and thermal efficiency of fuel cell	06
5.	**Biomass Energy:** Introduction to Biomass Energy Conversion, biomass gasification, biogas conversion, energy recovery form urban, industrial waste and landfills	06
6.	**Hydro Energy:** Electricity generation and Water pumping, Micro/Mini hydropower systems, Water pumping and conversion to electricity	05

Course Outcomes: In this course the students shall be able to understand the

CO1	design and analyze the solar thermal energy conversion system, solar PV system
CO2	design and analyze wind energy conversion system and its impact on grid integration
CO3	fuel cell technology and state of art fuel cells and its application in research area
CO4	. investigate the energy recovery from different biomass waste and electricity generation from micro/mini hydropower system

Text Books:

1.	D. P. Kothari, K. C. Singal, R. Ranjan, Renewable Energy Sources and Emerging Technologies, Prentice Hall of India, New Delhi, 2008.

Reference Books:

1.	S. N. Bhadra, D. Kastha, S. Banerjee, Wind Electrical Systems, Oxford Univ. Press, New Delhi, 2005
2.	S. A. Abbasi, N. Abbasi, Renewable Energy Sources and Their Environmental

Course Name	**:**	**Digital Signal Processing**
Course Code	**:**	**EER3008**
Credits	**:**	**3**
LTP	**:**	**3-0-0**

Course Objectives:

At the end of this course, the students should be able to
1. Understand the concepts of digital signal processing and transformation techniques
2. Apply concepts of digital signal processing to the design of digital filters

Total No. of Lecture - 42

Lecture Wise Breakup		**Number of Lecture**
1.	**Signals and Time Domain Representation** Classification of signals, typical signal processing operations, typical signal processing applications, why digital signal processing. Discrete- time signals, operations on sequences, the sampling process, discrete-time systems, time-domain characteristics of LTI discrete-time systems, state space representation of LTI discrete time systems. Frequency response, the transfer function. Digital two-pairs stability test.	10
2.	**Transformations** Domain representation of signals: the discrete-time Fourier transform, discrete Fourier transform, computation of the DFT of real sequences, linear convolution using the DFT, the z- transform, the inverse z- transform	8
3.	**Digital Processing of Continuous Time Signals** Sampling of continuous time signals, analysis filter design, anti- aliasing filter design, reconstruction filter design.	8
4.	**Digital Filters** Block diagram representation, signal flow graph representation, equivalent structures, Basic FIR digital filter structures, Basic IIR filters structures, all pass filters, tunable structures. Impulse invariance method of IIR filter design, bilinear transform method of IIR filter design, design of filter IIR notch filters, FIR filter design based on truncated Fourier series, FIR filter design based on frequency sampling approach, computer-aided design of digital filters.	16

Course Outcomes: By the end of this course, the students will be able to	
CO1	Realize the concepts of digital signal processing and transformation techniques
CO2	Apply various transformation and processing techniques for conversion of analog signals into discrete and digital domain
CO3	Apply the concepts of digital signal processing to design of digital filters

Suggested Books:

Sr. No.	**Name of Book/Authors/Publisher**	**Year of Publication/ Reprint**
1.	Mitra, Sanjit .k, Digital Signal Processing, Tata-McGraw-hill edition.	1997
2.	Antoniou, A., Digital Filters: Analysis & Design McGraw hill Book company.	1979

Course Name	**:**	**Advanced Mechatronics**
Course Code	**:**	**EER3009**
Credits	**:**	**03**
L T P	**:**	**3-0-0**

Course Objectives:

1. To impart knowledge and information about design and development of intelligent systems
2. To study the control of intelligent system
3. To study modelling and simulation of mechatronics system

Total No. of Lectures: 42

Lecture Wise Breakup		**Number of Lectures**
1.	**Understanding Mechatronics** Basic Components of Mechatronics and Advanced mechatronics Examples: Manufacturing, CNC Robotics, Transportation equipment, Medical equipment, Defense equipment, Space exploration, Sports, Smart homes, Smart Grid , Smart City	06
2.	**Hardware concept of Mechatronics** **(i)Transducers and Sensors**: Ultrasonic transducer, Laser ultrasonic, Hall Effect sensor, Variable reluctance sensor, Pressure sensor, and Accelerometer, **(ii)Signal condition devices** : Analog and Digital Circuits and Devices **(iii)Controllers** :Microprocessor based system, Microcontroller based system, Programmable Logic Controller based System **(iv)Actuators**: Mechanical, Electrical Piezoelectric, Hydraulic and Pneumatic, Electromechanical.	10
3.	**Software concept of mechatronics** Programming Languages, Assembly, C,C++ , Matlab ,Ladder ,Simulink etc. Real time system	06
4.	**Advance Mechatronics Approach** Systems Modeling and Simulation, transfer function, system response, Linear /non-linear system analysis, system stability Digital control Applications, , On- Off Control, Supervisory Controller , Direct Digital Controller ,P-I-D Controller	10
5.	System Fault Finding, Trouble Shooting	04
6.	**Mechatronics system hands on training and project design & development** Sensor/transducer system, Signal conditioning ,Controller, Actuator, Advanced design and development approach	06

Course Outcomes: By the end of this course, the student will be able to:	
CO1	The process involved in design, development and control of intelligent systems.
CO2	After going through this course students will be able to understand
CO3	Softwares in mechatronics
CO4	Modelling and simulation of mechatronics system

Reference Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	Tilak Thakur Mechatronics, Oxford University Press, 2016	2016
2.	C. De Silva. Mechatronics: An Integrated Approach. CRC Press, 2005	2005
3.	W. Bolton. Mechatronics: A Multidisciplinary Approach. 4th Edition, Pearson, 2008	2008

Course Name	**:**	**PLC and SCADA**
Course Code	**:**	**EER3010**
Credits	**:**	**03**
L T P	**:**	**3-0-0**

Course Objectives: At the end of the course, the student should be able to:

1. Understand the PLC operations, functions and ladder logic programming.
2. Acquire knowledge of the fundamentals of SCADA.
3. Understanding of the components in SCADA and its communication protocols.

Total No. of Lectures: 42

Lecture Wise Breakup		**Number of Lectures**
1.	**Computer based Control:** Implementing control system using computer or microprocessor, computer based controller, hardware configuration and software requirements. **Distributed Control Systems:** Meaning and necessity of distributed control; hardware components of DCS, DCS software.	6
2.	**Introduction Programmable Logic Controller (PLC):** PLC versus microprocessor/ microcontroller/computer, advantages and disadvantages of PLC, architecture and physical forms of PLC. **Basic PLC functions:** Registers, holding, input and output registers, timers and timer functions, counters and counter functions.	6
3.	**Intermediate PLC functions:** Arithmetic functions: addition, subtraction, multiplication, division and other arithmetic functions, number comparison and conversion. **Data Handling Functions of PLC:** Skip functions and applications, master control relay functions and applications, jump with non-return and return, data table, register and other move functions.	7
4.	**Bit functions of PLC:** Digital bit functions and applications, sequencer functions and applications. **Advance Function of PLC:** Analog input and output functions, Analog input and output modules, analog signal processing in PLC, PID control functions, network communication functions.	8
5.	**PLC programming:** PLC programming languages, Ladder programming, mneumonic programming and high level language programming.	7
6.	**SCADA:** Supervisory control versus distributed control, layout and parts of SCADA systems, detailed block of schematic systems, function of SCADA systems, data acquisition, monitoring, control, data collection and storage, data processing and calculation, report generation, MTU: functions, single and dual computer configurations of MTU. RTU: Functions, architect/layout, MTU-RTU communication and RTU-Field device communication, application of SCADA.	8

Course Outcomes: By the end of this course, the student will be able to:

CO1	Apply the concepts of PLCs arithmetic and data handling functions.
CO2	Apply the ladder logic programming to different engineering problems.
CO3	Apply the bit functions and advance functions of PLCs.
CO4	List and describe the hardware components, typical communications architectures and software/communication components of a SCADA system.
CO5	Describe common industrial applications of Supervisory Control and Data Acquisition (SCADA) systems.

Textbooks:

Sr. No	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	W.W. John,*Programmable Logic Controller Programming Methods and Applications*, Pearson Education	**2003**
2.	W.Bolton, *Programmable Logic Controller*, Elsevier	**2009**
3.	T. Thakur, *Mechatronics*, Oxford University Press.	**2016**
4.	S.A. Boyer, SCADA: *Supervisory Control And Data Acquisition*,ISA: The Instrumentation,	**2010**

	Systems, and Automation Society	

Reference books:		
Sr.No	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	J.D. McDonald and M.S. Thomas, *Power System SCADA and Smart Grids,*	**2015**
2.	R. Mehra, PLCs & SCADA : Theory and Practice, CRC Press	**2012**
3.	D. Reynders, E. Wright, and G.Clarke,*Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems*, Elsevier	**2004**
4.	D. Bailey, *Practical SCADA for Industry*, Elsevier	**2003**