1st Semester

Program Core

COURSE INFORMATION SHEET

Course code: EE501
Course title: Advanced Digital Signal Processing
Pre-requisite(s): Basics of signals and systems, transform methods, Filter theory.
Credits: 3 L T P
3 0 0
Class schedule per week: 3 Lectures
Class: M.Tech
Semester / Level: I/05
Branch: Electrical Engineering
Name of Teacher:

Course Objectives:
This course enables the students to:

A.	Enumerate the basic concepts of signals and systems, frequency response of discrete-time systems using various techniques like Z-transform, Hilbert transform, DFT, FFT;
B.	Apply digital IIR and FIR filters applying different techniques and finally construct using different realisation structures.
C.	Illustration of the concept of Decimation and Interpolation, Sampling rate conversion by a rational factor, Multi stage implementation of sampling rate conversion.
D.	Development of adaptive filter and its application. adaptive linear combiner (ALC), Signal processing applications in the area of speech and image, Adaptive signal processing applications to biomedical engineering.
E.	Apply DSP processor in processing of 1D and 2D signals.

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

1.	State sampling theorem and reproduce a discrete-time signal from an analog signal; frequency response of discrete-time systems by applying Z-transform, understand the basic of Hilbert transform, DFT, FFT algorithms, STFT for spectral analysis.
2.	Apply FIR filters using filter approximation theory, frequency transformation techniques, window techniques and finally construct different realisation structures. Realization of IIR filters.
3.	Illustrate the concept of Decimation and Interpolation, Multi stage implementation of sampling rate conversion.
4.	Development of adaptive filter and its in the area of speech and image, Adaptive signal processing applications to biomedical engineering.
5.	Construct (structure) and recommend environment-friendly filter for real- time applications. Design FIR and IIR filters used as electronic filter, digital filter,

	mechanical filter, distributed element filter, waveguide filter, crystal filter, optical filter, acoustic filter, etc. Application of DSP processor.

SYLLABUS

EE501 Advanced Digital Signal Processing

Module 1: Introduction: (8L)

Overview of discrete time signal and systems, ADC and DAC conversion, Time domain analysis of discrete-time linear time invariant systems, Analysis and characterization of LTI systems using Z-transform, Frequency domain analysis of signals using DFT and FFT algorithm. Hilbert transform, Spectral analysis using DFT, Short term DFT.

Module 2: Filter function approximation, IIR and FIR filter design and implementation:(8L)

Review of approximation of ideal analog filter response. Buttorworth, Chebyshev type I & II, Digital filter structures: Direct form I & II, Cascade, Parallel and ladder realization. IIR filter designs based on impulse invariant and Bilinear transformation.Characteristic of FIR, Symmetric and antisymmetric FIR filters, design of linear phase FIR filters using windows and frequency sampling methods, comparison of FIR and IIR filters.

Module 3: Multirate signal processing: . (8L)

Decimation: Time domain characterization, frequency domain characterization, Interpolation, Sampling rate conversion by a rational factor, Multi stage implementation of sampling rate conversion

Module 4: Adaptive Filter: . (8L)

Introduction to adaptive filter, adaptive linear combiner (ALC), Signal processing applications in the area of speech and image, Adaptive signal processing applications to biomedical engineering

Module 5: DSP Processor and applications (8L)

Introduction to DSP processor, Types of architectures, DSP support tools, code composer studio, compiler, assembler and linker, Introduction TMS320 C6x architecture, functional units, fetch and execute packets, pipe lining, registers, linear and circular addressing modes. Convolution, DFT, FFT implementation using DSP processor

Books Recommended:

Text Book

1. John G. Proakis, Dimitris G. Mamalakis, Digital Signal Processing, Principles, Algorithms and Applications.

2. Alan V. Oppenheim Ronald W. Schafer, Digital Signal Processing, PHI, India.

Reference Book

1. Antonious, Digital Filter Design, Mc-Graw-Hill International Editions.
2. S. Salivahanan C Gnanapriya, Digital Signal Processing, Tata McGraw Hill Education Private Limited.
3. A. NagoorKani, Digital Signal Processing, McGraw Hill Education Private Limited.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester EndExamination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	1	1	1	1
CO2	1	1	3	1	1	1
CO3	1	1	2	3	2	1
CO4	1	1	1	3	3	3
CO5	1	2	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

1. Visualize different signal processing techniques in real time.
2. Application of real time implementation of digital filter

POs met through Gaps in the Syllabus:

Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:

Course Delivery Methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments

CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3,CD5
CO2	CD1, CD2, CD3,CD5
CO3	CD1, CD2, CD3,CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3,CD5

COURSE INFORMATION SHEET

Course code: EE503
Course title: Modern Control Theory
Pre-requisite(s): B.E./B.Tech. in ECE/EEE with basic courses on Control Theory
Co- requisite(s): Linear Algebra
Credits: 3L T P
3 0 0
Class schedule per week: 03
Class: M.Tech.
Semester / Level: I/05
Branch: Electrical Engineering
Name of Teacher:

Course Objectives:

This course enables the students to:

1.	state basic concepts of state variables, state diagrams, controllability, observability;
2.	extend comprehensive knowledge of mathematical modelling of physical system;
3.	illustrate basics of transformations and decompositions for controllability and observability tests;
4.	enhance skills with application of different control strategy for designing a control problem;
5.	design controller for any type of linear plants.

Course Outcomes:

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

CO1	demonstrate an understanding of the building blocks of basic and modern control systems by creating mathematical models of physical systems in input-output or transfer function form;
CO2	organize state representations to satisfy design requirements using transformations and decompositions;
CO3	examine state space equations for time domain analysis;
CO4	assess a system for its stability, controllability, and observability properties leading to design of controller and observer in a feedback control system;
CO5	aspire for pursuing a carrier in control, recognize the need to learn, to engage and to adapt in a world of constantly changing technology and play role of team leader or supporter of team.

SYLLABUS

EE503 Modern Control Theory

Module I

Background and Preview, Modelling, Highlights of Classical Control Theory; Block diagram, Transfer functions, State Variables and State Space description of dynamic systems, State diagrams, Differential equations to state diagrams, State diagrams to Transfer function, State diagrams to state and output equations, State equations from system's linear graph.

(8L)

Module II

Fundamentals of Matrix Algebra, Vectors and Linear Spaces, Simultaneous Linear Equations, Eigenvalues and Eigenvectors, Functions of Square Matrices, Similarity Transformations, CCF, OCF, DCF and JCF forms, Decomposition of Transfer Functions, The Caley-Hamilton Theorem and it's applications.

(8L)

Module III

Analysis of Continuous and Discrete-Time Linear State Equations, Local linearization of non-linear models, State Transition Matrix, Significance, Properties and Evaluation of STM, Stability analysis using direct method of Lyapunov.

(8L)

Module IV

Controllability and Observability concept for linear Systems, Relationship among Controllability, Observability and Transfer Functions, Invariant theorems on Controllability and Observability.

(8L)

Module V

Design of Linear Feedback Control Systems, pole placement design through state feedback,Design of servo systems, State observers, Design of Regulator Systems with observers, Design of control systems with Observers, Quadratic Optimal Regulator Systems.

(8L)

Books Recommended:

Text Book

1. Modern Control Theory by Brogan, Pearson, 3rd edition. (**T1)**
2. Systems and Control by Zak, 1st edition, Oxford University Press. **(T2)**
3. Modern Control System Theory by M. Gopal, New Age International(P) Ltd., 2^{nd} edition. (**T3**)
4. Automatic Control Systems by F. Golnaraghi and B.C.Kuo, Wiley Student Edition, 9^{th} edition. (**T4**)
5. Modern Control Engineering by K. Ogata, Pearson, 5^{th} edition (**T5)**

Reference Book

1. Digital Control & State Variable Methods – M. Gopal, Tata McGraw Hill Education. (**R1**)
2. Linear Systems by Thomas Kailath, Prentice-Hall Inc.,1980. (**R2**)

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester EndExamination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	1	3	-	-
CO2	3	-	1	3	-	1
CO3	3	1	2	3	-	1
CO4	3	2	2	3	2	2
CO5	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

POs met through Gaps in the Syllabus: PO5& PO6

Topics beyond syllabus/Advanced topics/Design:
Design optimization for industrial projects, Fractional order controller.

POs met through Topics beyond syllabus/Advanced topics/Design: PO5 & PO6

Course Delivery Methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3,CD5
CO2	CD1, CD2, CD3,CD5
CO3	CD1, CD2, CD3,CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3,CD5

COURSE INFORMATION SHEET

Course code: EE509
Course title: Advanced Power System Analysis
Pre-requisite(s): B.E./B.Tech. in ECE/EEE
Co- requisite(s):

Credits: 3	L	T	P
	3	0	0

Class schedule per week: 03
Class: M.Tech.
Semester / Level: I/05
Branch: Electrical Engineering
Name of Teacher:

Course Objectives:

This course enables the students:

1.	to define single-phase modeling of power system components;
2.	to describe steady state operation of large-scale power systems and to solve the power flow problems using efficient numerical methods suitable for computer simulation like N-R,FDLF, Continuation Load Flow, Series Load Flow;
3.	to understand power systems under abnormal conditions (short circuit) utilizing bus impedance matrix for short circuit analysis;
4.	to understand the effect on power system for different outage events by contingency analysis and assess the state estimation;
5.	to extend the knowledge for solving harmonic load flow analysis stating the causes for harmonic content and modeling component in harmonic domain.

Course Outcomes:

After completion of the course, the learners will be able to:

CO1	draw the impedance and reactance diagram and can explain different components modeling for load flow, short circuit, contingency analysis and harmonic analysis of power system;
CO2	solve load flow problems by different methods;
CO3	analyze the different abnormal (fault) conditions in power system utilizing efficient computer algorithm;
CO4	explain different factors affecting the power system security for single and multiple contingencies and thereby to take proper corrective action.
CO5	explain numerical methods for state estimation of power system.

SYLLABUS

EE509 Advanced Power System Analysis

Module I

Introduction: Modeling of power system component, Basic single-phase modelling, Generation, Transmission line, Transformers, Shunt elements.

(8L)

Module II

Load Flow Analysis: Introduction, Nature of load flow equations, Newton Raphson method: Formulation for load buses and voltage controlled buses in rectangular and polar co-ordinates, Computational steps and flow chart, Computational Aspects of Large Scale System - Introduction, Sparsity oriented technique for reducing storage requirements, Factorization.

(8L)

Module III

Decoupled Load Flow: Formulation, Fast decoupled load flow method, Continuation load flow technique, Series load flow technique. Harmonic Analysis - Power Quality, Sources, Effects of Harmonics, Harmonic load flowanalysis, Suppression of Harmonics.

(8L)

Module IV

Short Circuit Analysis: Introduction, Bus impedance matrix and its building algorithmthrough modifications, Fault calculation uses Zbus and its computational steps. Symmetrical and Unsymmetrical faults.

(8L)

Module V

Contingency Analysis: Introduction to power system security, Factors affecting power systemsecurity, Analysis of single contingencies, Linear sensitivity factors, Analysis of multiplecontingencies, Contingency ranking. State Estimation: Introduction, weighted least square technique, Statistics, Errors and estimates.

(8L)

Text Books:

1. Power System Analysis - John J. Grainger, William D. Stevenson, Jr.
2. Power System Analysis - L. P. Singh

Reference Books:

1. Electric Energy Systems Theory - An Introduction, O.L. Elgerd.
2. Computer Modelling of Electrical Power Systems - J. Arrillaga, N.R. Watson
3. PowerSystem harmonic Analysis, J. Arrillage, B.C. Smith, et al.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester EndExamination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	2
CO2	3	3	3	3	2	2
CO3	3	3	3	2	3	2
CO4	3	3	3	2	2	3
CO5	3	3	2	2	2	3

COURSE INFORMATION SHEET

Course code: EE507
Course title: ADVANCED POWER ELECTRONICS
Pre-requisite(s): Operating Principle of Semiconductor Devices
Credits: 03 L:3 T:0 P: 0 C: 03
Class schedule per week: 03
Class: M.Tech.
Semester / Level: I/05
Branch: Electrical Engineering

Course Objectives:
This course enables the students to:

A	Remember classifications of power converters based on different criteria such as soft switching/ hard switching and isolated/non-isolated configuration etc.
B	Explain the working principle of different class of power converters and relate them with different area of application
C	Analyse shortcomings of different types of power converters.
D	Evaluate cost of power converter based topology terms of dynamic parameters of system, overall efficiency and cost.
E	Design power converter based topologies for energy management.

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

CO 1	List different types of semiconductor devices and remember their operating characteristics. Explain the working principle of different semiconductor devices.
CO 2	Classify different types of power converters. Show suitability of a power converter for a particular application. Solve power management related problems with application of power electronics based topologies.
CO 3	Outline shortcomings of each class of power converters and solve those using proper modifications. Identify potential areas for power electronics applications.
CO 4	Estimate the cost and long term impact of power electronics technology on a large scale project of socio-economic importance.
CO 5	Design new power converter topologies and Plan to develop a power processing unit for a particular requirement in industrial plants as well as domestic applications.

Syllabus

Module I:

Power Electronic Devices: Diodes, Thyristor, Review of switching devices- operating principle, Static & dynamic characteristics, Datasheet ratings; Thermal characteristics of power devices; Sample Gate drive circuits. [8L]

Module II:
Switched Mode Power Supply:

Forward and flyback converter circuits: operation of flyback converter and waveforms analysis, operation of forward converter and waveforms analysis, Double ended forward converter, Push Pull converter, Half Bridge isolated converter, Full bridge isolated converter, Bidirectional power supplies , small signal analysis of DC-DC converters and closed loop control. [8L]

Module III:

PWM inverter modulation strategies & dual bridge: Sine wave with third harmonic, space vector modulation and predictive current control techniques; PWM rectifier; Input side bidirectional power flow requirement for regeneration & Dual Thyristor Bridge. Multi- level inverter : Basic topology and waveform, Diode clamped multilevel inverter, Flying capacitor multilevel inverter, cascaded multilevel inverter improvement in harmonics and high voltage application, comparison of different multilevel inverters, application of multilevel inverters; [8L]

Module IV:

Resonant Inverters: Operating principle of series resonant inverter, waveforms analysis, switching trajectory, losses and control, Operating principle of series resonant inverter with bidirectional switches, Frequency response of resonant series loaded, parallel loaded, and series parallel- loaded inverter, Parallel resonant inverter, ZCS resonant converter, ZVS resonant converter. [8L]

Module V:
Introduction to application oriented chips: Industrial PWM driver chips for power supplies such as UC 3843, 3825 or equivalent; Industrial gate driver chips for PWM voltage source inverters with isolation and protection circuits. Intelligent power modules [8L]

Books recommended:
TEXT BOOK

1. M.H. Rashid,“Power Electronics: Circuits, Device and Applications”,2nd Ed.n, PHI, New Jersey, 1993
2. Mohan, Underland, Robbins; Power Electronics Converters, Applications and Design, 3rd Edn., 2003, John Wiley & Sons Pte. Ltd.
3. M. D. Singh, K. B. Khanchandani, “Power Electronics”, 2nd Edn., Tata McGraw- Hill, 2007.

REFERENCE BOOK

1. R. Krishnan, “Electric Motor Drives: Modeling, Analysis and Control ”, 1st Edn., Prentice Hall,2001
2. B. K. Bose, “Modern Power Electronics & AC Drives” , 1st Edn., Prentice Hall, 2001
3. L. Umanand, “Power Electronics: Essentials & Applications”, 1st Edn. Wiley India Private Limited, 2009
4. Jeremy Rifkin, “Third Industrial Revolution: How Lateral Power is Transforming Energy, the Economy, and the World”, 1st Edn., St. Martin‟s, Press, 2011

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	2	2	1
CO2	3	3	3	3	2	2
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	3
CO5	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements) :

(1) Cost Evaluation of Power Electronics based installation based on reliability
(2) Application of artificial intelligence in power electronics.
(3) Study of impact of power electronics on society and environment

POs met through Gaps in the Syllabus: PO6

Topics beyond syllabus/Advanced topics/Design:

(1) Reliability analysis in power electronics topologies
(2) Application of adaptive algorithms in power electronics based systems

POs met through Topics beyond syllabus/Advanced topics/Design: PO6

Course Delivery Methods

CD 1	Lecture by use of boards/LCD projectors/OHP projectors
CD 2	Assignments/Seminars
CD 3	Laboratory experiments/teaching aids
CD 4	Industrial/guest lectures
CD 5	Industrial visits/in-plant training
CD 6	Self- learning such as use of NPTEL materials and internets
CD 7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD6
CO2	CD1, CD6,CD7
CO3	CD1, CD2, CD3,CD6,CD7
CO4	CD1, CD3,CD6,CD7
CO5	CD1,CD2,CD3,CD4,CD5,CD7

COURSE INFORMATION SHEET

Course code: EE571
Course title: Soft Computing Techniques in Electrical Engineering
Pre-requisite(s): Basics of signals and systems, Digital Signal Processing, Filter theory.
Credits: L: 3 T: 1 P: 0 C: 3
Class schedule per week: 4 lectures week
Class :M.Tech
Semester/level: II
Branch: Electrical Engineering
Name of Teacher:

Course Objectives: This course enables the students to:

1	Understand the basic of Soft Computing Techniques.
2	Acquainted with the solving methodology of soft computing technique in power systems operation and control.
3	Analysis of ANN based systems for function approximation in application to load forecasting.
4	Evaluate fuzzy based systems for load frequency control in power systems.
5	Design of different problems of optimization in power systems and power electronics.

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

CO1	Identify the soft computing techniques and their roles in building intelligent machines.
CO2	Recognize an appropriate soft computing methodology for an engineering problem.
CO3	Apply fuzzy logic and reasoning to handle uncertainty while solving engineering problems.
CO4	Analysis of neural network and genetic algorithms to combinatorial optimization problems.
CO5	Classify neural networks to pattern classification and regression problems and evaluated its imparts while being able to demonstrate solutions through computer programs.

Syllabus

Module - 1
Introduction to Soft Computing: Introduction, Definition of Soft Computing Techniques, Importance of Soft Computing, Main Components of Soft Computing: Fuzzy Logic, Artificial Neural Networks, Introduction to Evolutionary Algorithms, Hybrid Intelligent Systems, Single and multi-objective optimization.

[8L]

Module –2
Artificial Neural Network and Applications: Introduction, Artificial Neuron Structure, ANN Learning; Back-Propagation Learning, Properties of Neural Networks, Unsupervised learnings, Hopfield networks, Application of GN Models to Electrical Machine Modeling, Short Term Electrical Load Forecasting Using Generalized Neuron Model, Aircraft Landing Control System Using GN Model.

[8L]

Module - 3
Introduction to Fuzzy Logic and Genetic Algorithm: Introduction, Uncertainty and Information, Types of Uncertainty, Introduction of Fuzzy Logic, Fuzzy Set, Operations on Fuzzy Sets, Fuzzy Intersection, Fuzzy Union, Fuzzy Complement, Fuzzy Concentration, Fuzzy Dilation, Fuzzy Intensification, α-Cuts, Characteristics of Fuzzy Sets, Demorgan's Law, Fuzzy Cartesian Product, Various Shapes of Fuzzy

Membership Functions, Methods of Defining of Membership Functions, Fuzzy Relation, DefuzzificationMethods.Introduction to Genetic Algorithm, Crossover, Mutation, Survival of Fittest, Population Size, Evaluation of Fitness Function.

[8L]

Module-4

Applications of Fuzzy Rule Based System: Introduction, System's Modeling and Simulation Using Fuzzy Logic Approach, Selection of Variables, Normalization Range and Number of Linguistic Values, Selection of Shape of Membership Functions for Each Linguistic Value, Selection of Fuzzy Union and intersection Operators, Selection of Defuzzification Method, Steady State D.C. Machine Model, Transient Model of D.C. Machine, Fuzzy Control System, Power System Stabilizer Using Fuzzy Logic.

[8L]

Module-5

Applications of Soft Computing Techniques to Electrical Engineering: Applications of Artificial Neural Network, Genetic Algorithms, Fuzzy and Hybrid Systems for Power System Applications: voltage control, voltage stability, Economic load dispatch, Unit commitment, Condition monitoring. Applications of Soft Computing Techniques for Power Electronics and Control Applications.

[8L]

Text Books:

1Neural Networks: A Comprehensive Foundation – SimanHaykin, IEEE, Press, MacMillan, N.Y. 1994.
2. S. Rajasekaran, G. A. Vijayalakshmi, Neural Networks, Fuzzy logic and Genetic algorithms, PHI publication.
3. Fuzzy logic with Engineering Applications - Timothy J. Ross, McGraw-Hill International Editions.
4. Fuzzy Sets and Fuzzy logic: Theory and Applications - George J. Klir and Bo. Yuan, Prentice- Hall of India Private Limited.

Reference Books:

1. Chaturvedi, Devendra K, Soft Computing Techniques and its Applications in Electrical Engineering, Hardcover ISBN:- 978-3-540-77480-8, Springer.
2. Kalyanmoy Deb, Optimization for Engineering Design, PHI publication
3. Kalyanmoy Deb, Multi-objective Optimization using Evolutionary Algorithms, Willey Publication
4.Kevin Warwick, Arthur Ekwue, Rag Agarwal, Artificial intelligence techniques in power systems. IEE Power Engineering Series-22.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester EndExamination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	1			
CO2	3	2	1	2		1
CO3	3	1	2	3		1
CO4	2	2	2	3	2	2
CO5	2	2	3	1	3	3

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

1. Visualize different soft computing techniques in real time.
2. Hardware implementation of soft computing techniques in real time.

POs met through Gaps in the Syllabus: PO5 & PO6

Topics beyond syllabus/Advanced topics/Design:

Soft computing application to image processing, video processing.

POs met through Topics beyond syllabus/Advanced topics/Design: PO5 & PO6

Course Delivery Methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3,CD5
CO2	CD1, CD2, CD3,CD5
CO3	CD1, CD2, CD3,CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3,CD5

COURSE INFORMATION SHEET
(Programme Core)

Course code: EE502
Course title: Advanced Digital Signal Processing Laboratory
Pre-requisite(s): Basics of signals and systems, transform methods, Filter theory.
Credits: 2

	L	T	P
	0	0	4

Class schedule per week: 4
Class: M.Tech.
Semester / Level: I/05
Branch: Electrical Engineering
Name of Teacher:

Course Objectives:
This course enables the students to:

A.	enumerate the basic concepts of signals and systems and their interconnections in a simple and easy-to-understand manner through different mathematical operations like folding, shifting, scaling, convolutions, etc. using MATLAB; also gain Knowledge of TMS kit, digital image filter;
B.	construct different realization structures;
C.	determine transfer function and predict frequency response of discrete-time systems by applying various techniques like Z-transform, DFT and FFT using MATLAB;
D.	evaluate cost of filters in terms of memory space complexity, algorithm complexity and economic values;
E.	design and compose digital IIR and FIR filters using filter approximation theory, for optimal cost.

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

1.	convert analog signal into digital signals and vice-versa, generation of different signals and basic knowledge of TMS kit;
2.	compute frequency response of the systems using frequency transformation technique, DFT, DIF-FFT or DIT-FFT algorithm, window techniques and visualization using MATLAB;
3.	design FIR and IIR filters;
4.	evaluate performance of filter with time variant signals;

5.	recommend environment-friendly filter for different real- time applications such as optical filter design, acoustic filter design etc.

LIST OF EXPERIMENTS

1. Name: - ADC and DAC conversion considering sampling theorem and aliasing effect.

Aim: - Generation and representation of different types of signal, Implementation of Analog to digital and digital to analog conversion suitably considering sampling theorem and aliasing effect.

2. Name:- Linear convolution, Cross-correlation, Auto-correlation of two sequences.

Aim: Analysis of interaction of digital signal with digital system using **l**inear convolution of two sequences. Perform Linear convolution of two sequence using circular matrix method.

3. **Name:-** Discrete Fourier transform and Inverse- Discrete Fourier transform
Aim: Frequency domain analysis of signals using DFT and IDFT algorithms.

4.**Name**: DFT by DIT-FFT and DIF-FFT method.
Aim: Frequency analysis of discrete signal by applying DIT-FFT and DIF-FFT algorithm.

5. **Name:** IIR filter realization.
Aim: Design and implementation of IIR filter using Direct form I and Direct form-II structure.

6. **Name:** FIR filter realization.
Aim: Design and implementation FIR filter using Direct form I and Direct form-II structure.

7.**Name:** Familiarization with TMS-320C6713 DSP starter Kit, convolution of two sequence applying TMS-320C6713 DSP starter Kit.
Aim: Implementation of interaction of digital signal and system applying TMS- 320C6713 DSP starter Kit.

8. **Name:** DFT and IDFT using TMS-320C6713 DSP starter Kit.
Aim: To perform frequency analysis using DFT and IDFT by applying TMS-320C6713 DSP starter Kit.

9. **Name: A**daptive filter design and implementation in speech processing.
Aim: To remove noise from a 1D biomedical and speech signal by applying adaptive linear combiner (ALC).

10. **Name**: Fundamentals on image processing. Noise suppression from digital image.

Aim: To change the intensity of specific part of given gray scale image. To write a program to remove Salt &pepper type noise from a given gray scale image using mean and median filters.

11. **Name:** Noise suppression from digital image using adaptive filter.
Aim: Write a program to remove Gaussian noise from given image by applying adaptive filter/ Artificial neural network.

Books Recommended:

1. Digital signal processing and applications with C6713 and C6416 DSK by RulphChassaing, wiley publication.
2. Real-Time digital signal processing based on the TMS320C6000 by Nasser Kehtarnavaz, ELSEVIER publication
3. DSP applications using C and the TMS320c6x DSK by RulphChassaing, Wiley Publication.

Reference Books:

1. Antonious,Digital Filter Design,Mc-Graw-Hill International Editions.
2. WavelateTransform,S.Rao.
3. WavelateAnalysis:"The scalable structure of Information"Springer2008–Howard L.Resinkoff,RaymondO.Wells

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Group project evaluation, Progressive and End semester evaluations

DIRECT ASSESSMENT

Direct Assessment

Assessment Tools	**% Contribution during CO Assessment**
Progressive Evaluation	60
End Semester Evaluation	40

Progressive Evaluation	**% Distribution**
Day to day performance & Lab files	30
Quiz (zes)	10
Viva	20
End Semester Evaluation	**% Distribution**
Examination Experiment Performance	30
Quiz	10

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	1	-	-	-
CO2	3	2	1	2	-	1
CO3	3	1	2	3	-	1

CO4	2	2	2	3	2	2
CO5	2	2	3	1	3	3

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):
1. Visualize different signal processing techniques in real time.
2. Application of real time implementation of digital filter.
.

POs met through Gaps in the Syllabus: PO5 & PO6

Topics beyond syllabus/Advanced topics/Design:
Adaptive signal processing, Image processing.

POs met through Topics beyond syllabus/Advanced topics/Design: PO5 & PO6

Course Delivery Methods

CD	**Course Delivery methods**
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3,CD5
CO2	CD1, CD2, CD3,CD5
CO3	CD1, CD2, CD3,CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3,CD5

2nd Semester

Programme Electives

(Power System, Control System

and

Power Electronics Courses)

COURSE INFORMATION SHEET
(Program Elective A)

Course code: EE583 R2
Course title: Renewable Sources of Electrical Energy and Grid Integration
Pre-requisite(s): Power Electronics and Power System
Credits: L: 3 T: 0 P: 0
Credits: 3
Class schedule per week: 03
Class: M.Tech
Semester / Level:II/05
Branch: EEE
Name of Teacher:

Course Objectives: This course enables the students to:

1	Understand about different renewable sources of electrical energy
2	Analyse maximum generation from SPV, and its realization through boost converter
3	Understand different control techniques for different types of wind generator technologies.
4	Controller design in d-q frame for grid following/grid supporting mode of inverter operation..
5	Understand basic working principles of hydrogen electrolyzers, Fuel cell, Biomass fuel production, Battery Energy Storage system

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

CO1	Articulate the basic operation of different renewable sources and battery storage sources for electrical energy generation.
CO2	Develop the mathematical modeling of SPV and wind turbine along with controllers to extract maximum power.
CO3	Explain the operation of PMSG, DFIG and their controllers.
CO4	Design the controllers in d-q frame in grid interactive mode.
CO5	Explain the working principles of hydrogen electrolyzers, Fuel cell, Biomass fuel production, Battery Energy Storage system.

Syllabus

Module I: Drivers of Renewable sources of electrical energy [4L]
Decarburization, Energy security, Expanding energy access, Present status of RE generation and future projections, Wind energy, Solar energy, RE grid integration challenges, Non-controllable variability, Partial unpredictability, Locational dependency

Module II: Basics of solar PV [6L]
Solar PV systems: Fundamentals of solar cell, semiconductors as basis for solar cells materials and properties, P-N junction, sources of losses and prevention, I-V and P-V characteristics, Array design

Module III: Power converters and control for PV [15L]
Characteristics and circuit models, Topologies, principles of operation. Maximum power tracking algorithms and Buck-Boost Converter, single- and three-phase inverters for PV, Inverter control in d-q frame, PLL technique , Harmonic analysis, and filter design, Current injection control at unity power factor, reactive power control, interconnection standards such as IEEE 1547, Steady state and dynamic models of PV systems and implementation in simulation tools

Module IV: Wind Energy: Power converters and control for wind generators [12L]
Overview of wind turbine systems and configurations, Detailed analysis of doubly fed induction generator and PMSM based wind generators, Dynamic modeling of wind generators, Field oriented control of rotor side and grid side power converters, Control methods for maximum power extraction, active and reactive power control, Basic operation of DFIG

Module V: Basics of other renewable sources [8L]
Biomass Energy System: Biomass – various resources, energy contents, technological advancements, Hydrogen production: Hydrogen Electrolyzer, Fuel Cell, Energy storage: Battery – types, equivalent circuit, performance characteristics, battery power control

Text Books:

1. Renewable energy technologies - R. Ramesh, Narosa Publication.
2. Energy Technology – S. Rao, Parulkar
3. Non-conventional Energy Systems – Mittal, Wheelers Publication.

Reference Books:

1. Wind and solar systems by Mukund Patel, CRC Press.
2. Solar Photovoltaics for terrestrials, Tapan Bhattacharya.
3. Wind Energy Technology – Njenkins, John Wiley & Sons.
4. Solar & Wind energy Technologies – McNeils, Frenkel, Desai, Wiley Eastern.
5. Solar Energy – S.P. Sukhatme, Tata McGraw Hill.
6. Solar Energy – S. Bandopadhay, Universal Publishing.
7. Guide book for National Certification Examination for EM/EA – Book 1

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar/Assignment	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	3	3	3	2
CO2	3	3	3	3	2	2
CO3	3	3	3	2	3	2
CO4	3	3	3	2	2	3
CO5	3	3	2	2	2	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):
Different Standards and technical guidelines of RES operation and integration.

POs met through Gaps in the Syllabus: Part of PO5.
Topics beyond syllabus/Advanced topics/Design: Guidelines, MATLAB simulation

POs met through Topics beyond syllabus/Advanced topics/Design: PO5 & PO6

Course Delivery Methods

CD	**Course Delivery methods**
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3, CD5
CO2	CD1, CD2, CD3, CD5

CO3	CD1, CD2, CD3, CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3, CD5

Course code: EE 599
Course title: Digital Power System Protection
Pre-requisite(s): Basic knowledge on faults, digital system and signal processing.
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 3
Class: M. Tech

Course Objectives: This course enables the students to:

1	Analyse and apply the principles and algorithms of digital relaying in power system
2	Analyse, Compare and imbibe the efficacy of digital relaying for protection of power equipment with flexibility as well as adaptability
3	Develop adequate skills to integrate appropriate protection measures for power equipment and system as a whole
4	Have commensurate technological up gradation related to state-of-the-art in power system protection

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

CO1	Comprehend the evolution of digital relaying and analyze its potent applications in a synthetic way
CO2	Apply the concepts of digital relaying methodologies for smart grid
CO3	Implement concepts of digital relaying for power equipments
CO4	Compare and contrast the unique advantages of digital protection over conventional and skilfully design emerging advanced power system integrity protection schemes
CO5	Apply the concepts skilfully for AC/DC Microgrid protection

Syllabus

Module 1:	**Introduction**	[7 L]
Evolution of digital relay, digital relay fundamentals; layout and elements of the digital relays; concept of sampling and aliasing required for digital relaying; sliding window concept.		
Module 2:	**Evolution of digital Relaying algorithms**	[10 L]
Phasors Estimation using Full-cycle Discrete Fourier Transform (DFT); Half-cycle DFT; discrete Cosine Transform, Least Error Square technique; frequency estimation in digital relays and practical conditions for selection of various algorithms.		
Module 3:	**Digital protection for generator and transformer**	[12 L]
Introduction to digital differential relays; Digital differential Protection for Generators, Transformers, Directional/Non-directional Overcurrent and Earth fault relays; Coordination of Overcurrent relay in an interconnected network, primary/backup relay pair determination.		
Module 4:	**Digital protection of Transmission lines**	[6 L]
Computation of direction and impedance for digital distance relays; detection of power swing and blocking technique; double-circuit transmission line protection; multi-terminal transmission line protection; Series compensated transmission line protection; synchro-phasor based SIPS for transmission lines.		

Module 5:	Microgrid Protection [5 L]
Microgrid Protection: Protection of dc microgrid: Review and challenges; AC microgrid protection: Problems and solutions; Insight into hybrid ac-dc microgrid protection	

TEXT BOOKS:

1. Digital Power System Protection, S. R. Bhide, PHI Publications, 2014
2. Power System Relaying, Stanley H. Horowitz, A.G. Phadke, 3rd edition, Willey Publications, 2008
3. T.S.M. Rao, "Digital Relay / Numerical relays ", Tata McGraw Hill, New Delhi, 2005
4. Bhavesh Bhalaja, R.P Maheshwari, Nilesh G.Chothani "Protection & Switchgear", Oxford Publisher, 2011

REFERENCE BOOKS:

1. Computer Relaying for Power Systems, A.G. Phadke, James S. Thorp, 2nd edition, Willey Publications, 2009
2. Y.G. Paithankar and S. R Bhide, "Fundamentals of Power System Protection", Prentice Hall of India, 2003

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	3	3	2
CO2	3	2	3	3	2	3
CO3	3	2	3	3	3	3
CO4	2	2	3	2	2	2
CO5	3	2	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

POs met through Gaps in the Syllabus:

Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:

Course Delivery Methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3,CD5
CO2	CD1, CD2, CD3,CD5
CO3	CD1, CD2, CD3,CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3,CD5

Course code: EE 539
Course title: Power System Dynamics
Pre-requisite(s): Knowledge of basic power system and control system courses.
Co- requisite(s):
Credits: 3 L T P
3 0 0
Class schedule per week: 3
Classes per week Class: M. Tech.
Semester / Level: I/05
Branch: EE
Name of Teacher:

Course Objectives
This course enables the students to:

1.	know the basic classification of power system stability;
2.	understand the concept of dynamic model of synchronous machine excitation system;
3.	investigate the concept of excitation system and load modelling;
4.	examine the concept of small signal stability and transient stability.

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

CO1	differentiate between different states and stability;
CO2	describe the dynamic model of single and multi-synchronous machine system;
CO3	describe the modelling of excitation system of a synchronous machine;
CO4	explain the static and dynamic load modelling;
CO5	examine the small signal stability of single and multi-machine system and evaluate the transient stability of an electrical system.

SYLLABUS
EE539 Power System Dynamics

Module I (8L)
Introduction to Power System Stability problem: Stability classification - Small signal & Transient stability, Rotor angle & Voltage stability, Hierarchy of controls in a Power System.

Module II (8L)
Synchronous Machine Modelling: Basic equations, dqo transformation, equations of motion.

Module III (8L)
Excitation System: Requirements of excitation system, Elements of excitation system, Types of excitation system, Modelling of excitation system.

Module IV (8L)

Power System Loads: Static load models, Dynamic load models.

Module V (8L)

Small Signal (Steady State) Stability: Linearization, State matrix, modal analysis technique. Transient Stability Studies: Network performance equations, Methods of enhancement of transient stability, MATLAB Implementation.

Text Books:

1. Power System Stability and Control, P. Kundur.

Reference Books:

1. Electric Energy System Theory – O.I. Elgerd
2. Power System Dynamics – K.R.Padiyar

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester EndExamination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	2	3	-	1
CO2	3	3	2	2	1	1
CO3	3	3	2	2	1	1
CO4	3	3	2	2	1	1
CO5	3	3	2	2	1	1

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2:Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

POs met through Gaps in the Syllabus:

Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:

Course Delivery Methods

CD	**Course Delivery methods**
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3, CD5
CO2	CD1, CD2, CD3, CD5
CO3	CD1, CD2, CD3, CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3, CD5

Course Code: EE605 R1
Course Title: Micro-Grid Operation and Control
Pre-requisite(s): EE307 Electrical Power System Transmission and Distribution, EE351 Control System and EE353 Power Electronics
Credits: 3 L: 3 T: 1 P: 0
Class schedule per week: 04 Class: M.Tech.
Semester / Level: III/Elective
Branch: Electrical & Electronics Engineering
Name of Teacher:

Course Objectives
This course envisions imparting the following objectives to the students:

A.	To enumerate the necessity of active distribution network and understand the principle of operation of microgrid.
B.	To expose the responsibility of controllers connected with DERs through IEEE standards 1547-2018.
C.	To feature the maximum power extraction from SPV and PMSG based wind turbine system and the working procedure of controllers.
D.	To assess different controllers for voltage and frequency restoration in microgrid.
E.	To outline the basic principles of protection of microgrids.

Course Outcomes
After the completion of this course, students will be able to:

1.	To explain the factors that require to develop a microgrid.
2.	Apply IEEE standard 1547-2018 while understanding the expectation from the controllers.
3.	Apply PWM based controllers to extract maximum power from SPV system
4.	Outline the steps and accordingly design primary controllers and evaluate their performance
5.	Explain the protection philosophy of islanding detection technique and the general microgrid protection.

Syllabus

Module 1: Concept of Microgrid **6**
Distributed generation and Microgrid concept: Introduction, Power System Structure, Traditional Grid, Microgrid definition and characteristics, typical micro grid configuration, distributed renewable energy technologies, non- renewable distributed generation technologies, interconnection of microgrids, technical and economical advantages of micro grid, key challenges.

Module 2:DER integration-I **6**

IEEE Standard for Interconnection (IEEE Std 1547™-2018): concept of area electric power system, point of common coupling, point of coupling, General interconnection technical specifications and performance Requirements, Reactive power capability and voltage/power control requirement, Voltage and Frequency disturbance ride-through requirements

Module 3 : DER integration-II **12**

Integration of solar sources: Modeling of the Entire PV Energy Conversion System, PV Controller, EES Controller, Grid Connection Control. Steps of control of entire PV energy system. Integration of wind power: Speed and power relations, Power extracted from the wind, Aerodynamic torque control, Control of a PMSG based wind energy generation system.

Module-4: DER Integration – III **8**

Hierarchical Microgrid Control, Local or primary Control :Droop Control, Droop Control in Inverter-based Distributed Generators, performance of primary controller, Secondary Control and Tertiary Control. Centralized and decentralized Energy Management System (EMS) in microgrids.

Module-5:

Microgrid Protection: Challenges in microgrid protection systems, Classification for microgrid protection: current limiter, centralized protection, distance protection. Islanding: Non-detection zone, Anti-islanding techniques, different islanding scenarios.

Course Evaluation: Individual assignment, Seminar before a committee, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements):

1. More focus on secondary and tertiary control in decentralized environment.
2. Detail in protection system for microgrid

POs met through Gaps in the Syllabus: 4 and 5

Topics beyond syllabus/Advanced topics/Design:

1. Risk evaluation with high penetration of RESs.
2. The infrastructure for implementing Demand Response programs.
3. Market operation in Indian context.

POs met through Topics beyond syllabus/Advanced topics/Design: 4 and 5 with higher level of satisfaction.

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
First Quiz	10
Mid Semester Examination	25
Second Quiz	10
Teacher's Assessment	5
End Semester Examination	50

Indirect Assessment

1. Students' Feedback on Course Outcome.

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	1	2	1	1	1	1	2	2		1		1	3	2	
CO2	2	2	1	1	1	2	1	2		1		3	3	2	2
CO3	3	3	3	3	2	2	2	2	1	1	2	2	3	3	3
CO4	3	3	3	2	2	2	2	2	1	1	2	2	3	3	3
CO5	3	3	3	1	2	2	2	2	1	1	2	2	3	3	2

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Mapping Between COs and Course Delivery (CD) methods

CD Code	Course Delivery Methods	Course Outcome	Course Delivery Method Used
CD1	Lecture by use of Boards/LCD Projectors	CO1	CD1, CD7, CD 8
CD2	Tutorials/Assignments	CO2	CD1 and CD9
CD3	Seminars	CO3	CD1, CD2 and CD3
CD4	Mini Projects/Projects	CO4	CD1 and CD2
CD5	Laboratory Experiments/Teaching Aids	CO5	CD1 and CD2
CD6	Industrial/Guest Lectures		
CD7	Industrial Visits/In-plant Training		
CD8	Self- learning such as use of NPTEL Materials and Internets		
CD9	Simulation		

Course code: EE 635
Course title: Wide Area Monitoring System
Pre-requisite(s): Power system courses, power electronics
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 3
Class: M. Tech
Semester / Level: III
Branch: EEE Name of Teacher:

Course Objectives
This course enables the students to:

A.	Grasp and apply the principles pertaining to power system monitoring and protection
B.	Analyse, compare and imbibe the efficacy of synchro-phasor technology over conventional monitoring techniques
C.	Design and implement improved network protection during stressed conditions
D.	Develop adequate skills to integrate appropriate protective measures for states estimation and enhanced situational awareness
E.	Commensurate technological up-gradation related to state-of-the art wide area monitoring system

Course Outcomes
After the completion of this course, students will be able to:

CO1.	Comprehend the evolution of computer relaying and analyze its potent applications in a wide area measurement system
CO2.	Apply the concepts of synchro-phasors for wide area monitoring and protection
CO3.	Design and implement concepts of synchro-phasors for adaptive protection
CO4.	Compare and contrast the unique advantages of phasor measurement unit over conventional protection
CO5.	Skilfully design emerging advanced power system integrity protection schemes for enhancing power system reliability and situational awareness

Syllabus

MODULE 1:

Introduction to Computer Relaying: Evolution of power system relaying from electromagnetic to static to computer relaying; Relay operating principles for computer relaying; Expected benefits of computer relaying, Computer relay architecture. Protection of Transmission Line using Computer Relaying Three zone protection of transmission line, algorithms for impedance calculations- Mann-Morrison algorithm - Three sample technique - Two sample technique - First and second derivative algorithms - Numerical integration methods. Protection of power system equipment using Frequency domain techniques Problems associated with differential protection of transformer and bus-bar, magnetic inrush current, LSQ algorithm, Fourier analysis of transformer protection

MODULE 2:

Introduction: Synchrophasor technology, advantages of synchrophasors over supervisory control and data acquisition (SCADA) system, challenges with synchrophasor measurement, world wide deployment of wide area measurement system (WAMS), application of synchrophasor data.

MODULE 3:

Phasor measurement units (PMUs) for wide area grid observability: Introduction, optimal placement of phasor measurement units (PMUs), need for optimal PMU placement for synchrophasors, algorithm for optimal PMU placement, observability index, optimal redundancy criterion.

MODULE 4:

WAMS based power network protection: WAMS architecture and communication, improved network protection during stressed conditions, online identification of protection element failure, adaptive protection.

MODULE 5:

Wide area security assessment: Introduction, state estimation, wide area severity index, data mining model, reliability evaluation and enhancement, situational awareness.

Text books:

1. A.G. Phadke, J.S. Thorp, 'Computer Relaying for Power Systems', John Wiley and Sons Ltd., Research Studies Press Limited, 2nd Edition, 2009.
2. A.G. Phadke, J.S. Thorp, 'Synchronized Phasor Measurements and Their Applications', Springer Publications, 2008
3. James Momoh, "SMART GRID: Fundamentals of Design and Analysis", IEEE (Power engineering series) – Wiley- Blackwell, April 2012.
4. D.K. Mohanta and J.B. Reddy (editors), "Synchronized phasor measurement for smart grid", Institution of Engineering and Technology 2017.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Group project evaluation, Progressive and End semester evaluations

DIRECT ASSESSMENT

Direct Assessment

Assessment Tools	**% Contribution during CO Assessment**
Progressive Evaluation	60

End Semester Evaluation	40
Progressive Evaluation	**% Distribution**
Day to day performance & Lab files	30
Quiz (zes)	10
Viva	20
End Semester Evaluation	**% Distribution**
Examination Experiment Performance	30
Quiz	10

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	3	3	2
CO2	3	2	3	3	2	3
CO3	3	2	3	3	3	3
CO4	2	2	1	2	2	2
CO5	3	2	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

POs met through Gaps in the Syllabus

Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:

Course Delivery Methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3,CD5
CO2	CD1, CD2, CD3,CD5
CO3	CD1, CD2, CD3,CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3,CD5

Course code: EE545
Course title: Modern Power System Planning and Reliability
Pre-requisite(s): Power system courses
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 3
Class: M.Tech
Semester :II
Branch: EEE
Name of Teacher:

Course Objectives:

1. Analyze the need of power system planning considering load forecasting models for short-term and long-term.
2. Analyze the concept of systems reliability and reliability mathematics applicable to power systems and to evaluate the different hierarchical levels of power system on reliability perspective.
3. Analyze the methodologies to solve power system generation system and network planning.
4. Propose on design modification to estimate the reliability enhancement and evaluate the research trend towards smart grid planning and integration of distributed generation planning.

Course Outcomes:

1. Apply the knowledge of basic planning aspects for load forecasting models.
2. To appraise the general reliability perspective with power system and to evaluate the different hierarchical levels of power system based on reliability perception.
3. Analyze the techniques for generation system and network planning and apply engineering knowledge, design techniques to prevent or to reduce the likelihood or frequency of failures at different hierarchical levels of power system.
4. To apply methods for estimating the reliability of new designs or expansion planning.
5. Formulate concepts for reliable smart-grid and micro-grid planning, reliable integration of distributed generation.

Syllabus:

Module 1
Objectives of planning : Long and short term planning - Load forecasting — characteristics of loads — methodology of forecasting — energy forecasting — peak demand forecasting — Non-weather sensitive forecast (NWSF), Weather-sensitive forecast (WSF), Total forecast, Annual and monthly peak demand forecast.

Module 2

Introduction to power system reliability: Failure Rate Model , Mean Time to Failures, Need for Power system Reliability Evaluation, Functional Zones, Hierarchical Levels, Adequacy Analysis at different Hierarchical Levels, Typical reliability criteria, Reliability worth, Markov processes, System reliability using network and state space method.

Module 3

Reliable Generation Planning: Fundamental economic analysis, Generation planning optimized according to generating unit categories (WASP), Generation planning optimized according to power plants (JASP), Introduction to Static Generation Capacity Reliability Evaluation, Capacity outage probability tables (COPT), Loss of load probability (LOLP) method, Loss of energy probability (LOLE) method, Frequency and duration approach. Introduction to spinning capacity reliability evaluation.

Module 4

Network planning and composite System Reliability Evaluation: Heuristic methods of network planning, Network planning by mathematical. optimization, Average interruption rate method for reliability evaluation of transmission system, the frequency and duration approach for reliability evaluation of transmission system, Stormy and normal weather effects on transmission system, Composite System Reliability Evaluation Considering Interconnection.

Module 5

Planning of Smart Grid and reliability assessment: Introduction, optimal placement of PMUs, reliable planning of microgrid, reliable planning and integration of distributed generation.

Text Books:

1. Modern Power System Planning, X, Wang and J.R. McDonald, McGraw-Hill Book Company.
2. Power System Reliability Evaluations - R. Billinton, Gordon and Breach Science Publishers, New York.

Reference Books:

1. Reliability Modeling in Electric Power Systems, J. Endrenyi, John Wiley & Sons, New York.
2. Power System Planning, R.L. Sullivan, McGraw-Hill International Book Company

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	Program Outcomes					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO 1	3	2	2	3	2	1
CO 2	3	2	3	3	2	2
CO 3	3	2	3	3	3	2
CO 4	2	2	2	2	3	1
CO 5	2	2	2	2	3	1

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

POs met through Gaps in the Syllabus:

Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:

Course Delivery Methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars

CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3, CD5
CO2	CD1, CD2, CD3, CD5
CO3	CD1, CD2, CD3, CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3, CD5

Course code: EE567

Course title: Smart Grid Technology
Pre-requisite(s): Power system courses, power electronics.
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 3
Class: M.Tech
Semester :II
Branch: EEE
Name of Teacher: Dr. T. Ghose

Course Objectives: This course enables the students:

1	To make the students understand the concept of smart grid, its components and challenges.
2	To confer the challenges of active distribution with high penetration of RESs.
3	To illustrate the working principle of PMU and its application in wide area monitoring system.
3	To understand commensurate technological up-gradation related to communication protocol and its application in smart grid.
4	To explain different demand response programmes.

Course Outcomes: After the completion of this course, a student will be able to:

CO1	To prioritize the elements essential to make the grid more smart.
CO2	Analysis the challenges involved with RESs in market operation and the role of energy storage devices to deal with the intermittency with RESs.
CO3	Demonstrate the DSP application to the function of PMUs and its application in WAMS.
CO4	Relate the importance of different types of communication protocols with the concept of smart grid.
CO5	Illustrate design concept involved with demand response Programmes.

Syllabus

Module-1: Introduction (5)
Basics about Power Grid operation, Smart Grid: The Definitions, Characteristics of Smart Grid, Traditional Grid Versus Smart Grid, Evolution of Smart Grid, Components of Smart Grid, smart grid operation and control architecture, The key challenges.

Module-2: Smart Grid and Generation (8)
Active Distribution network and Smart Grids: new technologies, advantages and disadvantages, Managing renewable intermittency in smart grid, Energy storage system for smart grid application, Dispatchable RES and Flexibility in high RES penetration, Market operation of renewable sources: RES aggregator, forecasting of RES power and financial risk.

Module-3: Smart Grid and transmission system (8)

Introduction, Wide area monitoring system, Phasor measurement units (PMUs) smart meters, multi-agent system technology, phasor measurement techniques: introduction, phasor estimation of nominal frequency signals, phasor updation using non-recursive and recursive updates, phasor estimation at off-nominal frequency input, hierarchy of phasor measurement systems, communication options for PMUs, functional requirements of PMUs and phasor data concentrators (PDCs).

Module 4: Smart Grid and Communication system (10)

Introduction, Role of communication in smart grids, Bluetooth-IEEE 802.15.1, ZigBee Technology, Ultra Wideband- IEEE 802.15.3a, TCP over wireless network: Overview of traditional TCP, Impact on the performance of TCP over wireless environment, Link Layer scheme (Snoop Protocol), The I-TCP protocol, The mobile TCP Protocol, IPv4 vs IPv6 : IPv4 and IPv6 addressing IPv4 and IPv6 header format, IPv4 option, IPv6 extension header, IPv5 routing architecture, QoS capabilities, IPv6 transition mechanism.

Module 5: Smart Grid and Demand Response: (8)

Introduction, demand response, Types of demand Response Programmes, Benefits of demand response programs, Advanced metering infrastructure, quantification of financial benefit of generation utility and distribution utility, Basic concept of Big data analysis,

Test Book:

1. Smart Grids: opportunities, developments and trends by A.B.M Shawkat Ali, publisher: Springer, ISBN: 978-1-4471-5209-5

2. A.G. Phadke J.S. Thorp, "Synchronized Phasor Measurements and their Applications", springer 2008

3.Wireless Communication & Networking by Vijay K. Garg, Elsevier.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	3	3	2
CO2	3	2	3	3	2	3
CO3	3	2	3	3	3	3
CO4	2	2	1	2	2	2
CO5	3	2	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

POs met through Gaps in the Syllabus:

Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:

Course Delivery Methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3,CD5
CO2	CD1, CD2, CD3,CD5
CO3	CD1, CD2, CD3,CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3,CD5

Course code: EE565
Course title: Power System Operation and Control
Pre-requisite(s): Power system, Control system.
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 3
Class: M. Tech
Semester / Level:II
Branch: EEE Name of Teacher:

Course Objectives: This course enables the students to:

1	To analyse different states in power system and transition between the states following the dynamic changes happened in power system.
2	To evaluate the nature of frequency change in Isolated and integrated system and thereby the control strategy for Generator.
3	To investigate different methods for economic operation of the power plant by fuel saving and scheduling of thermal and hydel units.
4	To provide the introductory concept on power system deregulation and its effect on power system operation.

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

CO1	To apply different operating condition and methods and technologies involved in control action according to different operating states of power system.
CO2	To design the primary and secondary controllers for automatic generation control.
CO3	To evaluate the economic generation scheduling in case of thermal units and combination of hydro-thermal units using different solution techniques.
CO4	To execute the frequency controller in multi-area system.
CO5	To identify the responsibilities of different agencies in power system operation and control in India and the charges in operation and control in deregulated environment.

Syllabus

Module – 1 [8L]

Introduction - Operating States, Preventive and Emergency control, Indian Electricity Grid Code, Coordination between different agencies in India, Power System Restructuring: Introduction, Regulation vs. Deregulation, Competitive Market for Generation, Advantages of Deregulation, Electric supply industry structure under deregulation in India. Restructuring Models

Module – 2 [8L]

Load Frequency Control - Introduction, Types of speed governing system and modelling, Mechanical, Electro-hydraulic, Digital electro-hydraulic governing system, Turbine modelling, Generator-load modelling, Steady-state and dynamic response of ALFC loop, the secondary ALFC loop, Integral control.

Module -3 [8L]

Multi-control-Area System - Introduction, Pool operation, Two-area system, Modelling the tie line, Static and dynamic response of two area system, Tie-line bias control, State space representation of two-area system, Generation allocation, Modern implementation of AGC scheme

Module – 4 [8L]

Optimum Operating Strategies- Introduction, Generation mix, Characteristic of steam and Hydro-electric units, Optimum economic dispatch- neglecting Loss and with transmission loss, Computational steps, Derivation of loss formula, Short-term Hydro-thermal scheduling, Reactive power scheduling.

Excitation System- Introduction, elements of an excitation system, Types of excitation system

Module – 5 [8L]

Unit Commitment - Introduction, Constraints in unit commitment, Thermal unit constraints, Hydroconstraints, Unit commitment solution method - Priority list method, Dynamic programming solution, Genetic Algorithm.

Text Books:

1. Electric Energy Systems Theory- An Introduction - Olle I. Elgerd, TMH, Edition 1983.
2. Power Generation Operation and Control - A.J. Wood, B.F. Wollenberg, John Wiley Sons, 2nd Edition

Reference Books:

1. Power System Restructuring and Deregulation- Trading, Performance and Information Technology- Loi Lei Lai (Editor), Wiley
2. Power System Stability and Control - P. Kundur, TMH
3. Indian Electricity Grid Code -Central Electricity Regulatory Commissionwww.cercind.gov.in/2010/ORDER/February2010/IEGC_Review_Proposal pdf
4. Power System Analysis – John J. Grainger & W.D. Stevenson, TMH, Edition 1994.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher’s Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students’ Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	3	3	2
CO2	3	2	3	3	2	3
CO3	3	2	3	3	3	3
CO4	2	2	1	2	2	2
CO5	3	2	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):
POs met through Gaps in the Syllabus:

Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:
Course Delivery Methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
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CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3, CD5
CO2	CD1, CD2, CD3, CD5
CO3	CD1, CD2, CD3, CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3, CD5

Course code: EE 591
Course title: Power System Deregulation
Pre-requisite(s): Knowledge of basic power system courses.
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 3
Class: M.Tech
Semester / Level: II
Branch: EE
Name of Teacher:

Course Objective: This course enables the students to:

1	Define power system restructuring and distinguish between regulation and deregulation of electric supply industry.
2	Explain and relate different power system restructuring models.
3	Identify and analyse the different electricity trading mechanism.
4	Analyse and demonstrate different types of congestion management

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

CO1	Explain the regulation and deregulation of electric supply industry.
CO2	Explain different power system restructuring models.
CO3	Explain competitive wholesale electricity markets.
CO4	Demonstrate pricing of transmission services.
CO5	Analyse inter-zonal and intra-zonal congestion management

Syllabus

Module- 1 [8L]

Power System Restructuring: introduction, Regulation vs. Deregulation, Competitive Market for Generation, The Advantages of Competitive Generation, Electric Supply Industry Structure under Deregulation in India.

Module- 2 [8L]

Restructuring Models: Introduction, Monopoly, Single Purchasing Agent Model, Wholesale Competition Model, Pool Model, Bilateral, Different Independent System Operator Model.

Module- 3 [8L]

International Experiences: Introduction, North American Deregulation Process: California State, Canada, England and Wales, China.

Module- 4 [8L]

Competitive Wholesale Electricity Markets: Introduction, Bidding, Market Clearing and Pricing, Central Auction, Unit Commitment Based Auction Model, Market Power and Mitigation.

Module- 5 [8L]

Transmission Pricing: Introduction, cost components of Transmission system, pricing of transmission services, location based marginal costing. Congestion Management: Introduction, Different ways of congestion management, impact on marginal price, congestion pricing, Inter-zonal and intra zonal congestion management.

Text Books

1. Power System Deregulation by Loi Lei Lai
2. Course material on "Operation and Management in Restructured Environment"-Edited by Dr. S.N. Singh, IIT, Kanpur

Reference Book

1. Understanding Electric Utilities and Deregulation by L. Philipson, N.L. Willis.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	**Program Outcomes**					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO 1	3	2	2	3	2	1
CO 2	3	2	3	3	2	2
CO 3	3	2	3	3	3	2
CO 4	2	2	2	2	3	1
CO 5	2	2	2	2	3	1

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

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Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:

Course Delivery Methods

CD	**Course Delivery methods**
CD1	Lecture by use of boards/LCD projectors
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MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3, CD5
CO2	CD1, CD2, CD3, CD5
CO3	CD1, CD2, CD3, CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3, CD5

Course code: EE 541
Course title: Condition Monitoring of Power Equipment
Credit: 3 **L-T-P: 3-0-0**
Pre-requisites: Knowledge of Basic Electrical Engineering, Field Theory, Physics.

Course Objectives: The objective of the course is to impart knowledge about

1. Brief overview of diagnostic tests for oil-paper insulation condition monitoring
2. Methods of non-destructive insulation condition monitoring
3. Overview of partial discharge test.
4. Overview of outdoor insulator condition monitoring

Couse outcome: After completing this course, the students would learn

1. About different diagnostic tests performed for condition assessment of oil-paper insulation
2. Pros and cons of different diagnostic tests.
3. About insulation modeling, parameters sensitive to insulation condition.
4. About partial discharge measurement for condition monitoring of insulation
5. About artificial contamination test of outdoor insulators.

Syllabus:

UNIT-I

Introduction, Brief overview of transformer insulation, Degradation of oil-paper insulation system, Degradation of oil, Degradation of paper, Chemical Diagnostic tests, Dissolved gas analysis (DGA), Degree of Polymerization Measurement, Furan Analysis, Conventional Electrical Diagnostic Tests, Insulation resistance test, Polarization index test, C-tanδ test.

8L

UNIT-II

Dielectric spectroscopy measurement, Polarization Depolarization current (PDC) measurement, Return Voltage Measurement (RVM), Frequency domain spectroscopy (FDS) measurement, Advantages of FDS measurement over time domain measurement.

6L

UNIT-III

Dielectric Response Function and Insulation Model, Mathematical Model of Dielectric Response, Oil Conductivity, Paper Conductivity, Relating Oil and Paper Conductivities with Insulation Condition, Modeling of Recovery Voltage, Modeling Dielectric Response in Frequency Domain, Dissipation Factor, Circuit Model, Identification of Equivalent Model Parameters, Calculating RV from Equivalent Model, Calculating Dissipation Factor From Equivalent Model, Calculating Complex Capacitance from Equivalent Model. Impulse Testing: Impulse testing of transformers, Detection and classification of Impulse Faults.

12L

UNIT-IV

Partial Discharge (PD) basics, PD equivalent model-PD currents-PD currents PD measuring circuits—Straight and balanced detectors-Location and estimation of PD in power apparatus- PD measurement by non-electrical methods-Calibration of PD detectors.

6L

UNIT-V

Contamination flashover phenomena-Contamination Severity- Artificial contamination tests, Determination of ESDD, Laboratory testing versus in-service performance-Case study.

6L

Text Books:

1. T. K. Saha and P. Purkait, "Transformer Ageing: Monitoring and Estimation Techniques", (1st Edition) John Wiley and Sons, 2017.
2. S. Chakravorti, D. Dey and B. Chatterjee, "Recent Trends in the Condition Monitoring of Transformers-Theory, Implementation and Analysis", (1 st Edition) Springer-Verlag London, 2013.
3. IEC-60720 "Artificial pollution tests on high voltage insulators to be used on a.c. systems", Int'l. std. IEC 60507 1991.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher’s Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students’ Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	Program Outcomes					
	PO1	PO2	PO3	PO4	PO5	PO6
CO 1	3	2	2	3	2	1
CO 2	3	2	3	3	2	2

CO 3	3	2	3	3	3	2
CO 4	2	2	2	2	3	1
CO 5	2	2	2	2	3	1

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

POs met through Gaps in the Syllabus:

Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:

Course Delivery Methods

CD	**Course Delivery methods**
CD1	Lecture by use of boards/LCD projectors
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MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3, CD5
CO2	CD1, CD2, CD3, CD5
CO3	CD1, CD2, CD3, CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3, CD5

Course code: EE521R1
Course title: Power Quality and Control
Pre-requisite(s): Power System, Power Electronics, Renewables
Credits: 03 L:3 T:0 P:0 C: 03
Class schedule per week: 03
Class: M. Tech
Semester / Level: II/02

Course Objectives:

A.	Enumerate different standards of common power quality phenomena.
B.	Understand power quality monitoring and classification techniques.
C.	Investigate different power quality phenomena causes and effects.
D.	Understand different techniques for power quality problems mitigation.

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

1.	Outline the various power quality phenomenon's, their origin and monitoring.
2.	Analyze the significance of transient over voltages, their origin and mitigation methods.
3.	Study the impact of harmonic distortion and mitigation methods through filter design.
4.	Understand the voltage regulation methods with distributed resources.
5.	Assess and integrate power quality issues for microgrids with distributed energy resources.

Syllabus

Module-I

Introduction–Overview of power quality, Power quality: concepts and definition, Power quality and voltage quality, International power quality standards, and regulations, General classes of power quality problems, CBEMA and ITI Curves, Power quality terms, Power frequency variations, Concern about the power quality, EMC standard. [8L]

Module-II

Loads which causes power quality problems, Long-duration voltage variations, Short-duration voltage variations, Voltage imbalance, Waveform distortion, Voltage sags and interruptions, sources of sags and interruptions, Estimating voltage sag performance, Sensitivity of equipment to voltage sag. Transient over voltages – Source of transient over voltages, power quality monitoring [8L]

Module-III

Power system harmonics: Harmonics, Inter-harmonics, Intra-harmonics, Sub-harmonics, Difference between harmonics and transients, Voltage and current distortion, Harmonic indices and standards, Sources of harmonic distortion, Effects of harmonic distortion, Mitigation and control techniques, Harmonic filters. [8L]

Module-IV

Transients: origin and classifications, Capacitor switching transient, Lightning-load switching, Non-linear device switching, Impact on users, Protection, Mitigation. [8L]

Module-V

Power factor correction, Zero voltage regulation, Reactive power compensation, Load balancing using load compensation techniques: active and passive shunt/series compensation, DSTATCOM (Distribution Static Compensators), DVR (Dynamic Voltage Restorers), UPQC (Universal Power Quality Conditioners [8L]

Textbooks and References

1. Surya Santoso, H. Wayne Beaty, Roger C. Dugan, Mark F. McGranaghan, "Electrical Power Systems Quality", McGraw-Hill, 2002.
2. Bollen, M.H.J, "Understanding Power Quality Problems: Voltage sags and interruptions", IEEE Press, New York, 2000.
3. C. Sankaran, "Power Quality" CRC Press
4. Arindam Ghosh, Gerard Ledwich, "Power quality enhancement using custom power devices", Springer, 2002.
5. Angelo B. Baggini, "Handbook of power quality", Wiley, 2008
6. Arrillaga, J, Watson, N.R., Chen, S., "Power System Quality Assessment", Wiley, New York, 2000

Course code: EE579
Course title: Industrial Instrumentation and Control
Pre-requisites: Electrical Measurement and Instrumentation
Co-requisites:
Credits: L:3 T:0 P:0
Class schedule per week: 03
Class: MTech
Semester/Level: II
Branch: Control/ EEE
Name of Teacher:

Course objectives

This course aims to provide the students with adequate knowledge about:

A.	The control strategies used in industrial instrumentation systems.
B.	The operating principles of sensors and systems used for the measurement of physical variables such as force, torque, velocity, pressure, flow, level, etc.
C.	Application aspects of sensors and measurement systems used in professional practice, specifically in industrial automation.
D.	Sensor signal conditioning, Data transmission techniques, selection criteria.

Course Outcomes

After the completion of this course, students will be able to:

1.	Understand the basics of industrial instrumentation and signal transmission techniques used in an instrumentation system.
2.	Impart knowledge about the static and response characteristics of first order and higher order measurement system.
3.	Understand the control mechanisms in an instrumentation system.
4.	Acquire knowledge about transmitters and understand the working of flow meters and level measurement systems.
5.	Understand the calibration, installation, and other aspects of pressure measurement. Learn about the digital and smart transmitters used in industries.

Syllabus

Module 1 **Lecture hours: 8**

Industrial Instrumentation systems: Types of industrial variables and measurement systems elements - sensors and transducers for different industrial variables like pressure, level, flow, etc. Sensor scaling. Industrial signal conditioning systems: Amplifiers, Filters, A/D converters for industrial measurements. Basics of Data transmission: IEEE-488 bus, RS 232 and RS 485 interface. HART protocol.

Module II **Lecture hours: 8**

Calibration and response of Industrial Instrumentation: Standard testing methods and procedures, performance characteristics, response characterization — static and dynamic, response to different forcing functions.

Module III **Lecture hours: 8**

Control System Instrumentation: Transducers, Transmitters, Final control elements, Schemes, and analysis of typical process control strategies: Feedforward control, Ratio control, Cascade control, Split-Range control.

Module IV **Lecture hours: 8**

Displacement and proximity gauges. Introduction to electronic transmitters. Pneumatic and Hydraulic Instrumentation system. Limit switch, Proximity Sensors. Flow measurement: Flowmeter. Criteria for selection of flowmeters. Measurement of Level: Point level measurement, Continuous level measurement.

Module V **Lecture hours: 8**

Measurement of Pressure. Actuator and Electronic pressure transmitters. Calibration, installation, signal processing and control of pressure measuring devices. Measurement accessories. Smart, Intelligent transmitters - features & advantages. IOT Transmitters.

Textbooks

1. Principles of Industrial Instrumentation, D. Patranabis, Tata McGraw Hill.
2. Instrumentation and Control, D. Patranabis, PHI.
3. Measurement Systems Application and Design, E.O. Doebelin, Tata McGraw Hill.
4. Fundamentals of Industrial Instrumentation, Alok Barua, Wiley.
5. Measurement & Instrumentation: Trends & Applications, M.K. Ghosh, S. Sen, and S. Mukhopadhyay.

Reference books

1. Liptak B.G, Instrumentation Engineers Handbook (Measurement), Chilton Book Co.,
2. John G Webster, Measurement, Instrumentation and Sensors, Handbook, CRC Press.
3. Principles of Measurement, John Bentley, Pearson.
4. Measurement and Instrumentation Principles, A. S. Morris, Butterworth-Heinemann.
5. Industrial Instrumentation, K. Krishnaswamy, New Age International Publishers, New Delhi.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	Program Outcomes					
	PO1	PO2	PO3	PO4	PO5	PO6
CO 1	3	2	2	3	2	1
CO 2	3	2	3	3	2	2
CO 3	3	2	3	3	3	2
CO 4	2	2	2	2	3	1
CO 5	2	2	2	2	3	1

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

POs met through Gaps in the Syllabus:

Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:

Course Delivery Methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3, CD5
CO2	CD1, CD2, CD3, CD5
CO3	CD1, CD2, CD3, CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3, CD5

Course Code: EE564
Course title: Advance Power System Laboratory
Credits: 02 L: 0 T:0 P: 04 C: 02

Class schedule per week: 4

Class: M. Tech

Semester / Level: II/05 Branch: Electrical Engineering

Name of Teacher:

Class schedule per week: 4

Course Objectives (CO)

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

1. Understand fundamental concepts of power system analysis, including load flow, fault studies, and frequency control.
2. Analyse symmetrical and unsymmetrical faults in IEEE standard bus systems using simulation tools.
3. Design and Simulate automatic generation control (AGC) and load frequency control (LFC) systems using MATLAB/Simulink.
4. Evaluate grid-following and grid-forming inverters under different operating conditions.
5. Implement and Interpret power system contingency analysis and inverter operations using advanced software tools.

Course Outcomes (CO)

After completing the course, students will be able to:

1. Explain the concepts of power system stability, faults, and control techniques.
2. Perform power flow and fault analysis in IEEE test bus systems using ETAP and MATLAB.
3. Develop and Simulate AGC, LFC, and inverter models for a power system using MATLAB and PSCAD.
4. Evaluate the transient response of power systems under different disturbances.
5. Design and Implement microgrid-based solutions for power system operation and control.

Syllabus

Experiment 1
Name: Power Flow Analysis
Objective: To develop IEEE 30 bus system in ETAP and analyse different loading conditions up to voltage instability using load flow method.
Experiment 2
Name: Symmetrical fault analysis

Objective: To develop IEEE 14 bus system in ETAP and observe the short circuit current for symmetrical fault in different buses and hence determine the SCR of each bus.

Experiment 3

Name: Unsymmetrical fault analysis

Objective: To develop IEEE 14 bus system in ETAP and observe the fault current for LG, LL, and LLG type fault in any one bus and compare the fault current of each type with the fault current observed in symmetrical fault on the same bus in previous experiment.

Experiment 4

Name: Load frequency control

Objective: Using MATLAB Simulink develop the load frequency control model and obtain the frequency deviation response for given condition.

Experiment 5

Name: Automatic generation control for two area system

Objective: Using MATLAB Simulink develop AGC model for a two-area system and hence obtain the frequency and power response for each area.

Experiment 6

Name: Grid Following Inverter operation

Objective: Using MATLAB Simulink model develop the single grid following inverter connected to grid.

Experiment 7

Name: Grid Forming Inverter operation

Objective: Using MATLAB Simulink model develop the single grid forming inverter connected to an active power load.

Experiment 8

Name: Induction motor starting

Objective: Use PSACD software to understand the transient involve in starting of Induction motor.

Experiment 9

Name: Inverter operation

Objective: Use PSCAD software to understand the inverter operation.

Experiment 10

Name: Contingency analysis

Objective: Write a MATLAB script for contingency analysis of given power network.

Text books:

1. J. D. Glover, M. S. Sarma, and T. J. Overbye, Power System Analysis and Design, 6th Edition, Cengage Learning, 2016.

2. A. R. Bergen and V. Vittal, Power System Analysis, 2nd Edition, Pearson Education, 2000.

Hadi Saadat, Power System Analysis, 3rd Edition, McGraw-Hill, 2010.

3. P. Kundur, Power System Stability and Control, McGraw-Hill Education, 1994.

4. B. M. Weedy, B. J. Cory, N. Jenkins, J. B. Ekanayake, and G. Strbac, Electric Power Systems, 5th Edition, Wiley, 2012.

5. J. J. Grainger and W. D. Stevenson, Power System Analysis, McGraw-Hill, 1994.

Reference Books

1. J. Arrillaga and C. P. Arnold, Computer Analysis of Power Systems, Wiley, 1997.

2. K. R. Padiyar, Power System Dynamics: Stability and Control, 2nd Edition, BS Publications, 2008.

3. T. Ackermann, Wind Power in Power Systems, 2nd Edition, Wiley, 2012.

Mapping of Course Outcomes onto Program Outcomes

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	1	3	2	1
CO2	3	3	3	3	2	2	3	2	2
C03	3	3	3	3	3	2	3	3	2
CO4	3	3	3	3	3	3	3	3	3
CO5	3	3	3	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

1. Design of real-time industrial projects.

POs met through Gaps in the Syllabus PO6

Topics beyond syllabus/Advanced topics/Design

Group assignments on practical use of power electronics in industry.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT:

Assessment Tool	% Contribution during CO Assessment
Progressive Evaluation: Lab Quiz (1)	1x10 = 10
Progressive Evaluation: Daily Evaluation	30
Progressive Evaluation: Viva	20
End Semester Evaluation: Experiment Performance	30
End Semester Evaluation: Lab Quiz (1)	10

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1, CD6
CO2	CD1, CD6, CD7
CO3	CD1, CD2, CD3, CD6,CD7
CO4	CD1, CD3, CD6,CD7
CO5	CD1,CD2,CD3,CD4,CD5,CD7

COURSE INFORMATION SHEET

(Program Elective B)

Course code: EE505
Course title: System Identification and Adaptive Control
Pre-requisite(s): Fundamentals of signal and system, Digital signal processing,

Credits:	L	T	P
	3	0	0

Class schedule per week: 3
Class: M.Tech.
Semester / Level: I/05
Branch: Electrical Engineering
Name of Teacher:

Course Objectives:
This course enables the students to:

A.	illustrate the process of system identification and interpret data-based identification techniques.
B.	understand the concepts of time invariant systems identification, and apply it to specific real time numerical problems.
C.	illustrate and summarize the techniques of adaptive control.
D.	derive necessary and sufficient conditions for Input/Output, Lyapunov (Direct and Indirect) stability.
E.	develop adaptive laws for On-line Parameter Estimation and derive schemes and procedures for Direct Model Reference Adaptive Control.

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

CO1	enumerate the process of system identification and apply the data based identification techniques to identify transfer functions of unknown plant models.
CO2	apply the static and dynamic system identification techniques to identify the estimated states for the unknown or perturbed time invariant plant models.
CO3	state and interpret the concepts of adaptive control and determine Input/output and Lyapunov stability of a LTI feedback system
CO4	apply various techniques or laws of adaptation for online parameter estimation and reproduce the results and write effective reports suitable for quality journal and conference publications.
CO5	design adaptive observers and model reference adaptive control for SISO and MIMO plants and simultaneously recognize the need to learn, to engage and to adapt in a world of constantly changing technology and play role of team leader or supporter of team.

<u>**SYLLABUS**</u>

Module 1:
Introduction to System Identification: Data based identification (System Response Methods, Frequency Response Methods, Correlation Methods). **8L**

Module 2:
Time Invariant Systems Identification: Static Systems Identification, Dynamic Systems Identification. **8L**

Module 3:
Introduction to Adaptive Control: Models for Dynamic Systems, Stability. **8L**

Module 4:
On-line Parameter Estimation: Fundamentals of random signals, Spectral estimation, Optimum (Wiener and Kalman) linear estimation, Extended Kalman filter, Particle filter, Parameter Identifiers and Adaptive Observers. **8L**

Module 5:
Model Reference Adaptive Control (MRAC): Simple Direct MRAC Schemes, MRC for SISO Plants, Direct MRAC with Unnormalized Adaptive Laws, Direct MRAC with Normalized Adaptive Laws. **8L**

Books recommended:

Text Books:

1. Systems Identification: An Introduction – Karel J. Keesman, Springer, 2011.
2. Robust Adaptive Control - Petros A. Ioannou and Jing Sun, 1996.
3. Optimization, Estimation and Control - A.E. Bryson & Y.C. Ho
4. Applied Optimal Estimation - A. Gelb, NIT Press, Cambridge
5. Optimal Estimation, Identification and Control - RCK Lee, NIT Press, Combridge, Massachusetts, 1964.
6. Stochastic Optimal Linear Estimation and Control - J.S. Meditch, McGraw Hill, N.Y., 1969.

Course Evaluation:
Individual assignment, Theory (Quiz and End semester) examinations

<u>**Gaps in the syllabus (to meet Industry/Profession requirements)**</u>**:**
Design of real-time industrial projects.

POs met through Gaps in the Syllabus:PO5 & PO6

<u>**Topics beyond syllabus/Advanced topics/Design:**</u>

Advanced topic in adaptive signal processing, Artificial Intelligence Techniques.

POs met through Topics beyond syllabus/Advanced topics/Design: PO5 & PO6

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	1	1	3	1	1
CO2	2	1	1	2	1	1
CO3	2	1	2	2	1	2
CO4	2	2	2	3	3	3
CO5	2	3	3	1	1	3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1, CD6
CO2	CD1, CD6, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD5, CD7

Course code: EE553
Course title: Nonlinear Control System
Pre-requisite(s): Modern Control Theory
Co- requisite(s): Control system design
Credits: 3 L:3 T:0 P:0
Class schedule per week: 03
Class: M.E.
Semester / Level: II/5
Branch: EEE Name of Teacher:

Course Objectives: This course enables the students with concepts:

A.	of nonlinear properties and their types
B.	of linearization of nonlinear state equations
C.	to extend comprehensive knowledge of graphical and mathematical analysis of nonlinear physical system for study of stability;
D.	to illustrate basics of different design methods;
E.	to summarize them on regulation and tracking problems.

Course Outcomes:
After the completion of this course, students will be able to:

CO1	comprehend various nonlinear properties.
CO2	relate an appropriate methodology for analysis of the various types of nonlinearities.
CO3	organize different methodologies to demonstrate stability of different nonlinear control problems.
CO4	categorize different techniques like, feedback linearization, sliding mode, gain scheduling to regulation and tracking problems.
CO5	appraise and compile the different properties and methods of analysis and design for the need of continuous learning in order to create state of art based on advanced mathematical tools and pursue higher studies in premier institutes.

Syllabus

Module 1

Introduction to Nonlinear systems: Types of nonlinearities, Characteristics, Linear approximation of nonlinear systems, Linearization of nonlinear state differential equation, Phase plane analysis: Phase plane representation, Phase portrait, graphical method to obtain phase trajectory, Singular points, Limit cycle. [8L]

Module – II

Describing function analysis: Definition, Derivation of Describing functions for common nonlinear elements, Determination of amplitude and frequency of limit cycle using describing function technique. [8L]

Module - III

Lyapunov methods: Introduction, Basic concepts, Stability definitions, Stability theorems, Lyapunov functions for nonlinear systems, Methods for determination of Lyapunov functions, popov stability criteria. [8L]

Module – IV

Feedback Linearization: Motivation, Input-output linearization, Full state linearization, State feedback control: Stabilization, Tracking [8L]

Module – V

Sliding mode control and Gain Scheduling: Sliding mode control: Sliding mode control: Motivation, Stabilization, Tracking, Regulation via integral control; Gain Scheduling: Scheduling variables; Gain scheduled controller for nonlinear system. [8L]

Text Books:

1. Slotine and Li, "Applied Nonlinear Control", Prentice Hall, Englewood Cliffs, New Jersey 07632
2. M. Gopal, "Digital Control & State Variable Method", TMH.
3. B. C. Kuo, "Automatic Control System"7th Edition PHI
4. Hassan K. Khalil, "Non Linear Systems".

Reference:

S. Banerjee, "Nonlinear Dynamics" (NPTEL Lectures)

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Assignment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	2	2	2
CO2	3	3	2	3	2	3
CO3	3	3	3	3	3	3
CO4	3	3	3	3	3	3
CO5	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

1. Industry related control applications can be undertaken

POs met through Gaps in the Syllabus: PO5, PO6

Topics beyond syllabus/Advanced topics/Design: Artificial Intelligence

POs met through Topics beyond syllabus/Advanced topics/Design: PO5, PO6
Course Delivery Methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3, CD5
CO2	CD1, CD2, CD3, CD5

CO3	CD1, CD2, CD3, CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3, CD5

Course code: EE515
Course title: Control System Design
Pre-requisite(s): Fundamentals of Mathematics and Physics, Introduction to System Theory, Control Theory
Credits:3 L T P
3 0 0
Class schedule per week: 3
Class: M.Tech
Semester/level: II/05
Branch: Electrical Engineering
Name of Teacher:
Course Co-ordinator:

Course Objectives

This course enables the students to:

F.	To state the performance characteristics of control systems with specific design requirements and design objectives
G.	To understand the concepts of PD, PI, PID, lead, lag and lag lead controller design in time domain and frequency domain and apply it to specific real time numerical problems
H.	To apply the state feedback controller and observer design techniques to modern control problems
I.	To analyse the effects of different controllers and compensators on transient and frequency domain response
J.	To realize and then design digital and analog compensators.

Course Outcomes

After the completion of this course, students will be able to:

CO1	Identify the design objectives and requirements of control systems
CO2	Interpret the concepts of PD, PI, PID, lead, lag, lag lead, and discrete data controller design and apply it to solve some design problems
CO3	Apply the state feedback controller design and techniques and outline its effects on system's performance which includes transient response and robustness
CO4	To develop methodologies to design real time digital and analog compensators and reproduce the results and write effective reports suitable for quality journal and conference publications
CO5	aspire for pursuing a career in control, recognize the need to learn, to engage and to adapt in a world of constantly changing technology and play role of team leader or supporter of team

Syllabus

Module 1:
Performance characteristics of feedback control system & design specification of control loop. Different types of control system applications and their functional requirement. Derivation of load-locus (toque/ speed characteristics of load). Selection of motors, sensors, drives. Choice of design domain & general guidelines for choice of domain. Controller configuration and choice of controller configuration for specific design requirement. Fundamental principles of control system design. Experimental evaluation of system dynamics in time domain and frequency domain. [8]

Module 2:
Design with PD Controller: Time domain interpretation of PD controller, frequency domain interpretation of PD controller, summary of the effects of PD controller. Design with PI controller: Time domain interpretation of PI controller frequency domain interpretation of PI controller, summary of the effects of PI controller, design with PID controller, Ziegler Nichols tuning & other methods. [8]

Module 3:
Design with lag/lead/lag-lead compensator, time domain interpretation of lag/lead/lag-lead compensator, frequency domain interpretation of lag/lead/lag-lead compensator, summary of the effects of lag/lead/lag-lead compensator. Forward & feed-forward controller, minor loop feedback control, concept of robust design for control system, pole-zero cancellation design. [8]

Module 4:
Sate feedback control, pole placement design through state feedback, state feedback with integral control, design full order and reduced order state observer. [8]

Module 5:
Design of Discrete Data Control System: Digital implementation of analog controller (PID) and lag-lead controllers, Design of discrete data control systems in frequency domain and Z plane. [8]

Books recommended:
Text Books:
1. B.C. Kuo, "Automatic Control System", 7th Edition PHI. (T1)
2. M. Gopal, "Control Systems Principles & Design", 2nd Edition, TMH. (T2)
3. J.G. Truxal, "Automatic Feedback Control System", McGraw Hill, New York. (T3)
4. K. Ogata, "Discrete Time Control Systems", 2nd Edition, Pearson Education. (T4)

Reference Books:
1. Norman Nise, "Control System Engineering", 4th Edition. (R1)
2. M. Gopal, "Digital Control & State Variable Method", TMH. (R2)
3. B.C. Kuo, "Digital Control System", 2nd Edition, Oxford. (R3)

4. Stephanie, “Design of Feedback Control Systems”, 4th Edition, Oxford. (R4)

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher’s Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Student Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	3	2
CO2	3	2	3	3	3	3
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	3
CO5	2	2	3	3	3	2

Correlation Levels 1, 2 or 3 as defined below:

1. Sight (Low)   2. Moderate (Medium)   3. Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements)

1. Real time analog design of controllers.
2. Interfacing the controllers with the real time physical plants to identify the effects on system’s performance.

POs met through Gaps in the Syllabus: 3,4

Topics beyond syllabus/Advanced topics/Design

Simulation problems related to industry

POs met through Topics beyond syllabus/Advanced topics/Design 4, 5

CD	**Course Delivery methods**
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Self- learning such as use of NPTEL materials and internets
CD5	Simulation

MAPPING BETWEEN COS AND COURSE DELIVERY (CD) METHODS

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1,CD2,CD4
CO2	CD1, CD4
CO3	CD1,CD3,CD4, CD5
CO4	CD1,CD2,CD3,CD4, CD5
CO5	CD1,CD2,CD3,CD4, CD5

Course code: EE601
Course title: Process Measurement and Control
Pre-requisite(s): Instrumentation and Measurement
Co- requisite(s): control system
Credits: L:3 T:0 P:0
Class schedule per week: 03
Class: M.Tech
Semester / Level: 0X
Branch: control/ EEE
Name of Teacher:

Course Objectives

This course enables the students:

A.	Expose students to the advanced control methods used in industries and research.
B.	Understand various process model
C.	Understand process control
D.	Control system analysis and design
E	Understand various process model

Course Outcomes

After the completion of this course, students will be:

CO1	controller tuning
CO2	type of controller that can be used for specific problems in industry
CO3	design of controllers for interacting multivariable systems
CO4	design of digital control systems
CO5	Understanding of production line

Syllabus

Module 1 Fundamentals of Process: Control Elements of process control loop, Process Characteristics and their significance. Process gain, Process reaction curve, process time constant, step analysis method, finding time constant, dead time. [8L]

Module 2 Feedback Controller Tuning: Types of Controllers, Tuning methods, Selection of controller for specific application, Controller settings- evaluation criteria – 1/4th decay ratio, IEA, ISE, ITAE - determination of optimum settings for mathematically described process using time response and frequency response. [8L]

Module 3 Stability Analysis and Performance of Feedback Control systems: Concept of stability, Stability analysis of linear and linearised systems, principles, Bode Method, Controller tuning based on stability Control Performance via closed loop frequency Response, Control system factors influencing control Performance. [8L]

Module 4 Control strategies: Multi loop process control systems, Feedback-feed forward control,adaptive control, Smith predictor, internal model control. Cascade Control, Ratio Control, Selective Control, and Split-range Control with industrial applications. [8L]

Module 5 Analysis of Multivariable Systems Process Interaction: Effects of Interaction, Block representation and transfer function matrix interaction, relative gain array, resiliency, Morari resiliency index, Niederlinsky index Multivariable Control Singular Value Analysis, Selection of manipulated and Controlled Variables, Tuning of multiloop PID control systems, Decoupling and Multivariable control Strategies. [8L]

Text books:

1. "Process Control", F. G. Shinskey, McGraw Hill Book Company
2. "Process, Modeling, Simulation and Control for Chemical Engineers", W. L. Luyben, McGraw Hill.
3. D.R. Coughanour, 'Process Systems analysis and Control', McGraw-Hill, 2nd Edition, 1991.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar	10
Assignment	10
Semester EndExamination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	2	2	2	3	3
CO2	1	3	3	3	3	3
CO3	3	2	2	2	2	3
CO4	3	3	2	3	3	3
CO5	2	2	3	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):
Production related concept can be undertaken

POs met through Gaps in the Syllabus: PO5, PO6

Topics beyond syllabus/Advanced topics/Design:

1. **AI system**
2. **fluid mechanics**
3. **Industrial instrumentation and measurement**

Course Delivery Methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3,CD5
CO2	CD1, CD2, CD3,CD5
CO3	CD1, CD2, CD3,CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3,CD5

Course code: EE551
Course title: Optimal Control Theory
Pre-requisite(s): Fundamentals of Mathematics and Physics, Introduction to System Theory, Control Theory
Co- requisite(s):

Credits:	L:	T:	P:
	3	0	0

Class schedule per week: 03
Class: M.Tech.
Semester / Level: II/05
Branch: Electrical Engineering
Name of Teacher:

Course Objectives: This course enables the students to:

A.	to state the performance index of an optimal control system with specific design requirements and design objectives.
B.	to understand the concepts of calculus of variations, Euler Lagrange equations and apply it to specific real time numerical problems.
C.	to identify and then establish the Hamiltonian and Pontryagin's formulation from a assumed performance index and apply it to specific real time numerical problems.
D.	to develop methodologies that uses the concept of finite and infinite time lqr
E.	to develop methodologies that uses the concept of dynamic programming procedure to generate control law for a single variable and a multivariable processes subjected to uncertainties.

Course Outcomes
After the completion of this course, students will be able to:

CO1	identify the design objectives and requirements to set up a performance index for an Optimal Control System.
CO2	interpret the concepts of calculus of variations to establish Euler Lagrange Equation and apply it to solve some design problems.
CO3	establish the Hamiltonian and Ponryagin's formulation from the performance index and apply this concept to develop an optimal control law.
CO4	develop methodologies to formulate a control law by Pontryagin's Minimum Principle using Dynamic Programming method and reproduce the results and write effective reports suitable for quality journal and conference publications.
CO5	develop methodologies to formulate a control law using finite time and infinite time, time varying LQR concepts for regulator and tracking problems and Simultaneously recognize the need to learn, to engage and to adapt in a world of constantly changing technology and play role of team leader or supporter of team.

Syllabus

Module 1: Introduction [8]

Optimization overview, flow chart of linear optimal control technique, Parameter optimization, Minimization problem, Tracking problem, Regulator problem. Calculus of variation. Derivation of Eular-Lagrange equation. The problems of Lagrange, Mayer and Bolza.

Module 2: Euler-Lagrange Equation [8]

Application of the Eular-Lagrange Equation to a Linear, first order system, Langrange multiplier, Gradient based unconstrained minimization.

Module 3: Hamiltonian Formulation [8]

Formulation of the general nth-order system problem, The Hamiltonian formulation of classical mechanics, Modified Transversality conditions at t = tf.

Module 4: Pontryagins maximum principle [8]

Pontryagins maximum principle, Hamilton - Jacobi Equation, Application of variation approach to control problem.

Module 5: Optimal LQR Formulation [8]

Quadratic form of performance index; statement of LQR problem, solution of finite time and infinite time regulator problem, solution of Riccati equation, Frequency domain interpretation of LQR design, Stability & robustness properties of LQR design, Linear Quadratic Gaussian (LQG) control. Dynamic Programming: Multistage decision process, Concept of sub-optimization and principle of optimality, Recurrence relationship, computational procedure in dynamic programming.

TEXTBOOKS:

1. Optimal control system – D.S. Naidu, CRS Press, 2003.
2. Introduction to optimum design – Jasbir S. Vora – Elsevier 2006.
3. Modern Control Theory – J. T. Tou

REFERENCE BOOKS:

1. Digital Control & State Variable Methods – M. Gopal, Tata McGraw Hill Education. (**R1**)

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Assignment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	2	2	1
CO2	3	3	2	2	1	1
CO3	3	2	2	2	1	1
CO4	3	3	2	2	2	2
CO5	3	3	2	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

1. Online optimal control design of controllers.
2. Interfacing the controllers with the real time physical plants to identify the effects on system's performance.

POs met through Gaps in the Syllabus: PO3, PO4 Topics beyond syllabus/Advanced topics/Design:

(i) Advanced optimal control design methods for different control problems

POs met through Topics beyond syllabus/Advanced topics/Design: PO4

Course Delivery Methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1
CO2	CD1,CD2,CD3
CO3	CD1,CD2,CD3
CO4	CD1,CD2,CD3
CO5	CD1,CD2,CD3

Course Code: EE 555
Course Title: Statistical Control Theory
Pre-requisite(s): Mathematics, Statistics, Introduction to System Theory, Control Theory
Co- requisite(s):
Credits: L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Tech.
Semester / Level: II/5
Branch: Electrical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

A.	Describe and classify different types of random variables, random processes, probability density function and cumulative distribution function
B.	Estimate statistical properties of random variables and random processes such as expected value, variance, standard deviation and correlation functions.
C.	Evaluate autocorrelation functions for given power spectral density, correlate the mean square error of any system with the correlation functions and analyse the response of linear system to random inputs.
D.	Design real time Wiener filter, stored data Wiener filter and Kalman filter for any system.
E.	Recommend the techniques of statistical control to solve a problem and technologically upgrade the skills in the domain of statistical control theory.

Course Outcomes

After the completion of this course, students will be able to:

CO1	Enumerate properties of probability density function, cumulative distribution function, correlation functions and power spectral density of a random process
CO2	Describe different types of random variable and random processes
CO3	Calculate expected value, variance, standard deviation and correlation functions of a random variable and random process.
CO4	Analyse the response of linear system to random inputs.
CO5	Design a Wiener and Kalman filter for a system and compare with classical filters

Syllabus

Module 1:

Review of Probability theory. Random experiments. **Random Variables**: Definition. Classification. Cumulative distribution function. Probability density function. Functions of Random Variables. Expected values. Moments. Variance and Standard deviation. Markov and Chebyshev inequalities. Transform methods: Characteristic function; Probability generating function; Laplace transform of the pdf. Transformation of random variable. [8]

Module 2:

Multiple Random Variables: Vector random variables. Pairs of random variables. Independence of random variables. Conditional probability and conditional expectation. Multiple random variables. Functions of several random variables. Expected value of function of random variables. Jointly Gaussian random variables. Sums of random variables: Mean; Variance; pdf of sum of random variables. Sample mean and law of large numbers. Central Limit theorem. [8]

Module 3:

Random Processes: Definition. Specification: Joint distribution of time samples; Mean; Autocorrelation and Autocovariance functions. Discrete random processes: iid random processes; sum processes: Binomial counting and Random Walk processes. Continuous-time random processes: Poisson processes; Wiener process and Brownian Motion. Stationarity. Time Averaging and Ergodicity, Minimum mean square error filtering: Estimating a random variable with a constant; stored data wiener filter; Real time
wiener filter. [8]

Module 4:

Analysis and Processing of Random signals: Power spectral Density: Continuous and discrete; Power spectral density as a time average. Response of Linear Systems to random signals. Amplitude modulation by random signals. Optimum Linear systems. Estimating the Power spectral density. White noise. [8]

Module 5:

Markov Chains: Markov processes. Discrete-time Markov Chains. Continuous-time Markov Chains. Time reversed Markov Chains. **Linear stochastic control**: LQG problem, Kalman filter and separation principle, Introduction to stochastic differential equations and continuous time stochastic, control: Hamilton-Jacobi-Bellman equation, nonlinear filtering, Minimum variance control. [8]

Text books:

1. Probability and random Processes for Electrical Engineering- A. Leon-Garcia, 2nd Edition, Pearson Education.

Reference books:

1. Probabaility, Random Variables and Stochastic Processes- A. Papoulis and S. Unnikrishnan Pillai, Fourth Edition, McGraw Hill.
2. Random Signals- Detection, Estimation and Data Analysis, K. Sam Shanmugan & A.M Breipohl, Wiley; 1st Edition (July 1988)

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Student Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3		3	3	2	1
CO2	3		3	3	2	
CO3	3		3	3	2	1
CO4	3	3	3	3	3	3
CO5	3	3	3	3	3	2

Correlation Levels 1, 2 or 3 as defined below:

1. Sight (Low) 2. Moderate (Medium) 3. Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements)

1. Real time applications to meet industry requirements

POs met through Gaps in the Syllabus

1,3,4,5

Topics beyond syllabus/Advanced topics/Design

1. Simulation given to students as assignments

POs met through Topics beyond syllabus/Advanced topics/Design

1, 2, 3, 4, 5, 6

CD	**Course Delivery methods**
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Self- learning such as use of NPTEL materials and internets
CD5	Simulation

MAPPING BETWEEN COS AND COURSE DELIVERY (CD) METHODS

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1,CD2,CD4
CO2	CD1, CD4
CO3	CD1,CD3,CD4, CD5
CO4	CD1,CD2,CD3,CD4, CD5
CO5	CD1,CD2,CD3,CD4, CD5

Course code: EE579
Course title: Industrial Instrumentation and Control
Pre-requisites: Electrical Measurement and Instrumentation
Co-requisites:
Credits: L:3 T:0 P:0
Class schedule per week: 03
Class: MTech
Semester/Level: II
Branch: Control/ EEE
Name of Teacher:

Course objectives

This course aims to provide the students with adequate knowledge about:

A.	The control strategies used in industrial instrumentation systems.
B.	The operating principles of sensors and systems used for the measurement of physical variables such as force, torque, velocity, pressure, flow, level, etc.
C.	Application aspects of sensors and measurement systems used in professional practice, specifically in industrial automation.
D.	Sensor signal conditioning, Data transmission techniques, selection criteria.

Course Outcomes

After the completion of this course, students will be able to:

1.	Understand the basics of industrial instrumentation and signal transmission techniques used in an instrumentation system.
2.	Impart knowledge about the static and response characteristics of first order and higher order measurement system.
3.	Understand the control mechanisms in an instrumentation system.
4.	Acquire knowledge about transmitters and understand the working of flow meters and level measurement systems.

5.	Understand the calibration, installation, and other aspects of pressure measurement. Learn about the digital and smart transmitters used in industries.

Syllabus

Module 1 **Lecture hours: 8**

Industrial Instrumentation systems: Types of industrial variables and measurement systems elements - sensors and transducers for different industrial variables like pressure, level, flow, etc. Sensor scaling. Industrial signal conditioning systems: Amplifiers, Filters, A/D converters for industrial measurements. Basics of Data transmission: IEEE-488 bus, RS 232 and RS 485 interface. HART protocol.

Module II **Lecture hours: 8**

Calibration and response of Industrial Instrumentation: Standard testing methods and procedures, performance characteristics, response characterization — static and dynamic, response to different forcing functions.

Module III **Lecture hours: 8**

Control System Instrumentation: Transducers, Transmitters, Final control elements, Schemes, and analysis of typical process control strategies: Feedforward control, Ratio control, Cascade control, Split-Range control.

Module IV **Lecture hours: 8**

Displacement and proximity gauges. Introduction to electronic transmitters. Pneumatic and Hydraulic Instrumentation system. Limit switch, Proximity Sensors. Flow measurement: Flowmeter. Criteria for selection of flowmeters. Measurement of Level: Point level measurement, Continuous level measurement.

Module V **Lecture hours: 8**

Measurement of Pressure. Actuator and Electronic pressure transmitters. Calibration, installation, signal processing and control of pressure measuring devices. Measurement accessories. Smart, Intelligent transmitters - features & advantages. IOT Transmitters.

Textbooks

1. Principles of Industrial Instrumentation, D. Patranabis, Tata McGraw Hill.
2. Instrumentation and Control, D. Patranabis, PHI.
3. Measurement Systems Application and Design, E.O. Doebelin, Tata McGraw Hill.
4. Fundamentals of Industrial Instrumentation, Alok Barua, Wiley.
5. Measurement & Instrumentation: Trends & Applications, M.K. Ghosh, S. Sen, and S. Mukhopadhyay.

Reference books

1. Liptak B.G, Instrumentation Engineers Handbook (Measurement), Chilton Book Co.,
2. John G Webster, Measurement, Instrumentation and Sensors, Handbook, CRC Press.
3. Principles of Measurement, John Bentley, Pearson.
4. Measurement and Instrumentation Principles, A. S. Morris, Butterworth-Heinemann.
5. Industrial Instrumentation, K. Krishnaswamy, New Age International Publishers, New Delhi.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar	10
Teacher’s Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Student Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	2	1
CO2	3	1	3	3	2	1
CO3	3	1	3	3	2	1
CO4	3	3	3	3	3	3
CO5	3	3	3	3	3	2

Correlation Levels 1, 2 or 3 as defined below:

1. Sight (Low) 2. Moderate (Medium) 3. Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements)

1. Real time applications to meet industry requirements

POs met through Gaps in the Syllabus

1,3,4,5

Topics beyond syllabus/Advanced topics/Design

1. Simulation given to students as assignments

POs met through Topics beyond syllabus/Advanced topics/Design

1, 2, 3, 4, 5, 6

CD	**Course Delivery methods**
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Self- learning such as use of NPTEL materials and internets
CD5	Simulation

MAPPING BETWEEN COS AND COURSE DELIVERY (CD) METHODS

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1,CD2,CD4
CO2	CD1, CD4
CO3	CD1,CD3,CD4, CD5
CO4	CD1,CD2,CD3,CD4, CD5
CO5	CD1,CD2,CD3,CD4, CD5

Course code: EE513
Course title: Robotics and Automation
Pre-requisite(s): Engineering Mathematics, Signal and Systems, Control Theory, Basic programming knowledge.
Co- requisite(s):
Credits: L:3 T:0 P:0
Class schedule per week: 03
Class: M.Tech.
Semester / Level: I/05
Branch: Electrical Engineering
Name of Teacher:

Course Objectives:

This course enables the students to:

A.	To explain the characteristics of robots, discuss different types of sensors and basic programming languages used for robotics
B.	To relate direct and inverse kinematics problem of robots and apply methods to solve them and to use techniques for planning robot motions.
C.	To explain different methods for control of robotic manipulators.
D.	To recommend the use of robotic vision in different applications of robots.
E.	To relate real life problems with direct and inverse kinematics, appraise different controllers for the robots.

Course Outcomes:

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

1.	enumerate and explain characteristics of robots, sensors used in robots and basic programming languages
2.	correlate direct and inverse kinematics to real life problems and apply the algorithm to solve them
3.	explain and analyse different control techniques and evaluate planning algorithms for robot motions
4.	assess the use of computer vision/machine vision to different robot applications and appraise the use of artificial intelligence in different field of robotics
5.	solve real life applications using direct and inverse kinematics and simulate different controllers.

SYLLABUS

Module I:

Basic components of robotic systems. Robot classification. Robot specifications. Applications. Direct Kinematics: Coordinate frames; Rotations; Homogeneous coordinates; D-H representation; The Arm Equation. [8]

Module II:

Inverse Kinematics: Inverse kinematics problem, General properties of solutions, Tool configuration, Robotic work cell, Workspace analysis. Trajectory planning. Workspace envelope. Workspace fixtures. Pick and place operation. Continuous-path motion. Interpolated motion. Straight line motion. [8]

Module III:
Sensing and Control of Robot Manipulators: Different sensors in robotics: Range; Proximity; Touch; Torque; Force and others. Computed torque control; Near Minimum time control;Variable structure control; Non-Linear decoupled feedback control; Resolved motion and Adaptive control.
[8]

Module IV:
Robotic Vision: Image acquisition and Geometry. Pre-processing; Segmentation and Description of 3-D structures; Recognition and Interpretation. [8]

Module V:
Robot Arm Dynamics: Lagrange-Euler formulation; Newton Euler formulation; Generalized D'Alembert's equation.
Robot Programming Languages, Robot Intelligence and Task Planning: Characteristics of Robot level languages. Task level languages- with examples C, prolog. Assembly etc. Problem reduction; Use of predicate logic; Robot learning; Expert systems. [8]

TEXT BOOKS
1. Fundamental of Robotics: Analysis and Control- Robert J. Schilling.
2. Robotics: Control , Sensing ,Vision and Intelligence- K.S. Fu, R.C. Gonzalez and Lee.

REFERENCE BOOK
1. Robotics and Control – R. K. Mittal and I. J. Nagrath.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	3	3	3	2
CO2	3		3	3	3	3
CO3	3	3	3	3	3	3
CO4	3	3	3	3	3	3
CO5	3		3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):
Simulation to meet real time implementation of techniques for control of robots

POs met through Gaps in the Syllabus: **1,2,3,4,5,6**

Topics beyond syllabus/Advanced topics/Design:
Simulation given to students as assignments

POs met through Topics beyond syllabus/Advanced topics/Design: **1,2,3,4,5,6**

Course Delivery Methods

CD	Course Delivery Methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Self- learning such as use of NPTEL materials and internets
CD5	Simulation

MAPPING BETEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1,CD2,CD4
CO2	CD1,CD2,CD4
CO3	CD1,CD2,CD3,CD4,CD5
CO4	CD1,CD2,CD3,CD4,CD5
CO5	CD1,CD2,CD3,CD4,CD5

COURSE INFORMATION SHEET

Course code: EE575
Course title: Robust Control
Pre-requisite(s): Engineering Mathematics, Signal and Systems, Control Theory, Basic programming knowledge.
Co- requisite(s):
Credits: L:3 T:0 P:0
Class schedule per week: 03
Class: M.Tech
Semester / Level: II/05
Branch: Electrical Engineering
Name of Teacher:

Course Objectives:

This course enables the students to:

F.	To understand the utility of norms, vectors, signals and systems, controllability, stability, observability and detectability.
G.	To discuss regarding the Feedback interconnection & stability including Coprime factorization and stabilizing controllers.
H.	To explain model uncertainty and robustness including small gain theorem and kharitonov's result.
I.	To explain the working of H_2 and H_∞ control problems and solutions.
J.	To relate real life problems with H_2 and H_∞ control and identify practical challenges in posing control problems.

Course Outcomes:

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

6.	Compute the norms of transfer functions and transfer function matrices.
7.	Apply the concepts of coprime factorization to represent and analyze the stability of control systems.
8.	Interpret the robustness of the control system using Robust Stability and Robust performance measures.
9.	Explain the synthesis of stabilising controllers in H_2 and H_∞.
10.	Integrate theoretical knowledge of feedback interconnections and stabilizing controllers into practical applications, solving real-world control system problems.

SYLLABUS

Module I:

Introduction to Robust Control, Introduction to Linear Algebra, Linear Subspaces, Eigenvalues and Eigenvectors, Matrix Inversion Formulas, Invariant Subspaces, Vector Norms and Matrix Norms, Singular Value Decomposition, Semidefinite Matrices [6]

Module II:

Linear Systems: Descriptions of Linear Dynamical Systems, Controllability and Observability**,** Observers and Observer based Controllers, State Space Realizations for Transfer Matrices, Multivariable System Poles and Zeros**.** [6]

Module III:

Internal Stability and Performance Specifications: Hilbert Spaces, H_2 and H_∞Spaces, Computing L_2 and H_2 norms, Computing L_∞ and H_∞ norms, Feedback Structure, Well posedness of Feedback Loop, Internal Stability, Coprime Factorization over RH_∞, Weighted H_2 and H_∞ performance, Selection of Weighting functions, Bode's gain and phase relation, Bode's Sensitivity Integral. [10]

Module IV:

Controller Parametrization and $\boldsymbol{H_2}$ Optimal Control: Existence of Stabilizing Controllers, Parametrization of all stabilizing Controllers, Coprime Factorization Approach, Stabilizing Solution and Riccati Operator, Inner Functions, Introduction to Regulator Problem, Standard LQR and Extended LQR problem, Guarenteed Stability Margins of LQR, Standard H_2 Problem and Stability Margins of H_2 Controllers. [10]

Module V:

$\boldsymbol{H_\infty}$ Control: A Simplified H_∞ Control Problem, Optimality and Limiting Behavior, Minimum Entropy Controller, General H_∞ solutions, Relaxing Assumptions, H_2 and H_∞ Integral Control, H_∞ Filtering [8]

TEXT BOOKS

1. Essentials of Robust Control- Kemin Zhou with John C.Doyle, Prentice Hall, 1999.

REFERENCE BOOK

1. A Course in Robust Control Theory: A Convex Approach - Geir. E. Dullerud and Fernando G. Paganini, New York: Springer-Verlag, 1999.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

Gaps in the syllabus (to meet Industry/Profession requirements):
Simulation to meet real time implementation of techniques for control of robots

POs met through Gaps in the Syllabus: **1,2,3,4,5,6**

Topics beyond syllabus/Advanced topics/Design:
Simulation given to students as assignments

POs met through Topics beyond syllabus/Advanced topics/Design: **1,2,3,4,5,6**

Course Delivery Methods

CD	Course Delivery Methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Self- learning such as use of NPTEL materials and internets
CD5	Simulation

MAPPING BETEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1,CD2,CD4
CO2	CD1,CD2,CD4
CO3	CD1,CD2,CD3,CD4,CD5
CO4	CD1,CD2,CD3,CD4,CD5
CO5	CD1,CD2,CD3,CD4,CD5

COURSE INFORMATION SHEET

Course code: EE569
Course title: Electric Vehicles
Pre-requisite(s): Power electronics
Co- requisite(s):
Credits: 03 L:03 T:0 P:0 C:03
Class schedule per week: 03
Class: M.Tech
Semester / Level: II/05
Branch: EEE
Name of Teacher:

Course Objectives

This course enables the students to:

A.	Understand working of Electric Vehicles.
B.	Able to choose components for a given electrical vehicle design and dimension them according to the specification.
c.	To integrate electrical vehicle components into a system and design for necessary controls.
D.	To estimate and understand the requirement for the infrastructure, including various charging and power distribution solutions, required for electrical vehicles
E.	To evaluate an electrical vehicle design and infrastructure using modern tools.

Course Outcomes

After the completion of this course, students will be:

1.	List the different types of EVs
2.	Associate with the different architecture of EVs. Show suitability of a power converter in the EVs.
3.	Determine the rating of energy source requirement of EV
4.	Estimate the cost and long-term impact of control of power converters by DPWM on a large scale project of socio-economic importance.
5.	Modify existing EV architectural design. Design a new efficient EV having superior performance.

Syllabus

Module 1:

Introduction to Electric Vehicles: Evolution of Electric Vehicles, Electric Vehicles and the Environment, EV classification and comparison with internal combustion engine: Technology, Advantages and Disadvantages of EV, EV configurations, Parameters of EV systems

[4L]

Module 2:

Electric Machines in EV:

Working principle of DC machines, characteristics and types of DC machines, Overview of (speed torque characteristics) permanent magnet motor, BLDC motor, Electrical motor topologies and operations principles: radial, axial and transversal flux motors. Torque production and characteristics of induction, permanent magnet and reluctance motors, comparison of all motors' performance in EV [10L]

Module 3:

Converters in Electric vehicles

AC-DC and DC- DC converters, Inverters, Soft switching topologies for EV, Isolated Bidirectional converters in EV. [10L]

Module 4:

Energy storage for EV:

Energy storage requirements, Battery parameters, types of batteries, modelling of battery, SOC and depth of discharge of battery in EV, Electrical Design considerations of EV

[10L]

Module 5:

Charging Infrastructures:

Introduction, Understanding charging economics, commercial charging and pricing models, Load managements for large scale EV integration [12L]

Text Books (T):

1. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003
2. C. C. Chan, K. T. Chau: Modern Electric Vehicle Technology, Oxford University Press Inc., New York 2001

Reference Books (R):

1. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design M. Ehsani, Y. Gao, S. Gay and Ali Emadi CRC Press 2005
2. Electric and Hybrid Vehicles: Design Fundamentals Iqbal Husain CRC Press 2003

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT -
1. Students' Feedback on Course Outcome

Mapping Between Course Outcomes and Program Outcomes

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	2	2	1
CO2	3	3	3	3	2	2
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	3
CO5	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements) Controller implementation using fixed point arithmetic

POs met through Gaps in the Syllabus: PO5

Topics beyond syllabus/Advanced topics/Design

Design of battery charging infrastructure

POs met through Topics beyond syllabus/Advanced topics/Design: PO5

Course Delivery methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Mini projects/Projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of NPTEL materials and internets
CD9	Simulation

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD6
CO2	CD1, CD6, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD5, CD7

Course code: EE565
Course title: Power System Operation and Control
Pre-requisite(s): Power system, Control system
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 3
Class: M. Tech
Semester / Level: II
Branch: EEE
Name of Teacher:

Course Objectives:This course enables the students to:

1	To analyse different states in power system and transition between the states following the dynamic changes happened in power system.
2	To evaluate the nature of frequency change in Isolated and integrated system and thereby the control strategy for Generator.
3	To investigate different methods for economic operation of the power plant by fuel saving and scheduling of thermal and hydel units.
4	To provide the introductory concept on power system deregulation and its effect on power system operation.

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

CO1	To apply different operating condition and methods and technologies involved in control action according to different operating states of power system.
CO2	To design the primary and secondary controllers for automatic generation control.
CO3	To evaluate the economic generation scheduling in case of thermal units and combination of hydro-thermal units using different solution techniques.
CO4	To execute the frequency controller in multi-area system.
CO5	To identify the responsibilities of different agencies in power system operation and control in India and the charges in operation and control in deregulated environment.

Syllabus

Module – 1 [8L]

Introduction - Operating States, Preventive and Emergency control, Indian Electricity Grid Code, Coordination between different agencies in India, Power System Restructuring: Introduction, Regulation vs. Deregulation, Competitive Market for Generation, Advantages of Deregulation, Electric supply industry structure under deregulation in India. Restructuring Models

Module – 2 [8L]

Load Frequency Control - Introduction, Types of speed governing system and modelling, Mechanical, Electro-hydraulic, Digital electro-hydraulic governing system, Turbine modelling, Generator-load modelling, Steady-state and dynamic response of ALFC loop, the secondary ALFC loop, Integral control.

Module -3 [8L]

Multi-control-Area System - Introduction, Pool operation, Two-area system, Modelling the tie line, Static and dynamic response of two area system, Tie-line bias control, State space representation of two-area system, Generation allocation, Modern implementation of AGC scheme

Module – 4 [8L]

Optimum Operating Strategies- Introduction, Generation mix, Characteristic of steam and Hydro-electric units, Optimum economic dispatch- neglecting Loss and with transmission loss, Computational steps, Derivation of loss formula, Short-term Hydro-thermal scheduling, Reactive power scheduling. Excitation System- Introduction, elements of an excitation system, Types of excitation system

Module – 5 [8L]

Unit Commitment - Introduction, Constraints in unit commitment, Thermal unit constraints, Hydro constraints, Unit commitment solution method - Priority list method, Dynamic programming solution, Genetic Algorithm.

Text Books:

1. Electric Energy Systems Theory- An Introduction - Olle I. Elgerd, TMH, Edition 1983.
2. Power Generation Operation and Control - A.J. Wood, B.F. Wollenberg, John Wiley 7 Sons, 2nd Edition

Reference Books:

1. Power System Restructuring and Deregulation- Trading, Performance and Information Technology- Loi Lei Lai (Editor), Wiley
2. Power System Stability and Control - P. Kundur, TMH
3. Indian Electricity Grid Code -Central Electricity Regulatory Commissionwww.cercind.gov.in/2010/ORDER/February2010/IEGC_Review_Proposal.pdf
4. Power System Analysis – John J. Grainger & W.D. Stevenson, TMH, Edition 1994.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher’s Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	3	3	2
CO2	3	2	3	3	2	3
CO3	3	2	3	3	3	3
CO4	2	2	1	2	2	2
CO5	3	2	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

POs met through Gaps in the Syllabus:

Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:

Course Delivery Methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3, CD5
CO2	CD1, CD2, CD3, CD5
CO3	CD1, CD2, CD3, CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3, CD5

Course code: EE611
Course title: Physiological Control Systems
Pre-requisite(s): Knowledge on basic biomedical instrumentation
Co- requisite(s):
Credits: L:3 T:0 P:0
Class schedule per week: 3
Class: M. Tech
Semester / Level: II
Branch: EEE
Name of Teacher:

Course Objectives
This course enables the students:

A.	Introduction to the physiological concepts and mathematical tools that they will need to understand and analyse these physiological control systems.
B.	Extend comprehensive knowledge of Structures and mechanisms responsible for the proper functioning of these systems.
C.	Enhance skills how these complex systems operate in a healthy human body
D.	Use linear control theory to model and analyse biological systems
E.	Nonlinear Analysis of Physiological Control Systems

Course Outcomes
After the completion of this course, students will be:

CO1	Understanding of different physiological system
CO2	Able to model and simulate
CO3	Can designed a control strategy
CO4	Identification of complex control system
CO5	aspire to take active role in developing state-of-the-art biomedical and allied system solutions and indulge in life-long learning.

Syllabus

Module-1: **Introduction**: Systems Analysis, Physiological Control Systems Analysis, Differences between Engineering and Physiological Control Systems, Mathematical Modeling: Generalized System Properties, Models with Combinations of System Elements, Linear Models of Physiological Systems, Distributed-Parameter versus Lumped Parameter Models, Linear Systems and the Superposition Principle [8]

Module-2: **Static Analysis of Physiological Systems**: Open-Loop versus Closed-Loop Systems, Determination of the Steady-State Operating Point, closed and open loop Regulation of Cardiac Output, Regulation of Glucose, Chemical Regulation of Ventilation, The Gas Exchanger, The Respiratory Controller, Closed-Loop Analysis: Lungs and Controller Combined.
[8]

Module-3: Time-Domain Analysis of Linear Control Systems: Linearized Respiratory Mechanics: Open Loop versus Closed-Loop, Open-Loop and Closed-Loop Transient Responses: First and second-Order Model, Impulse Response, Step Response, Open-Loop versus ClosedLoop Transient Responses, Reduction of the Effects of External Disturbances, Reduction of the Effects of Parameter Variations, Integral Control, Derivative Feedback, Transient Response Analysis, Frequency Response of a Model of Circulatory ontrol, requency Response of the Model, Frequency Response of Glucose-Insulin Regulation. [8]

Module-4: Stability Analysis: Model of Cheyne-Stokes BreathinCO2 Exchange in the Lungs Transport Delays Contents Controller Responses Loop Transfer Functions [8]

Module-5: Nonlinear Analysis of Physiological Control Systems: Nonlinear versus Linear Closed-Loop Systems Phase-Plane Analysis Local Stability: Singular Points Method of Isoclines Nonlinear Oscillators Limit Cycles The van der Pol Oscillator Modeling Cardiac Dysrhythmias The Describing Function Method Methodology Application: Periodic Breathing with Apnea Models of Neuronal Dynamics Hodgkin-Huxley Mode The Bonhoeffer-van der Pol Model
[8]

Text book:
Physiological Control Systems by M. C. K. Khoo, PHI, 2001

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar	10
Assignment	10
Semester End Examination	50

INDIRECT ASSESSMENT –
1. Students' Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	2	3	3
CO2	1	2	3	3	3	3
CO3	3	2	2	2	2	3
CO4	3	3	2	3	3	3
CO5	2	2	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

1. Biomedical related concept can be undertaken

POs met through Gaps in the Syllabus:

PO5,PO6

Topics beyond syllabus/Advanced topics/Design:

1. Electrophysiology systems
2. correlation between Actual system and simulation result
3. Process Measurement of physiology

Course Delivery Methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3, CD5
CO2	CD1, CD2, CD3, CD5
CO3	CD1, CD2, CD3, CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3, CD5

COURSE INFORMATION SHEET

Course code: EE552
Course title: Control system Design Lab
Pre-requisite(s): Fundamentals of Mathematics and Physics, Introduction to System Theory, Control Theory, Control System Design
Credits: 2 L:0 T:0 P:4
Class schedule per week: 4
Class :M.Tech
Semester/level:II/05
Branch: Electrical Engineering
Name of Teacher:
Course Co-ordinator:

Course Objectives:

i. To state the performance characteristics of control systems with specific design requirements and design objectives;
ii. To understand the concepts of PD, PI, PID, lead, lag and lag lead controller design in time domain and frequency domain and apply it to specific real time numerical problems
iii. To apply the state feedback controller and observer design techniques to modern control problems and analyse the effects on transient and frequency domain response;
iv. To realize and then design digital and analog compensators.

Course Outcomes:

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

i. Identify the design objectives and requirements of control systems;
ii. Interpret the concepts of PD, PI, PID, lead, lag, lag lead, and discrete data controller design and apply it to solve some design problems;
iii. Apply the state feedback controller design and techniques and outline its effects on system's performance which includes transient response and robustness;
iv. To develop methodologies to design real time digital and analog compensatorsand reproduce the results and write effective reports suitable for quality journal and conference publications ;
v. aspire for pursuing a carrier in control, recognize the need to learn, to engage and to adapt in a world of constantly changing technology and play role of team leader or supporter of team.

Lab Experiments:

1. **Design of Servo Position Control**
   Objective: To obtain the servo plant model, design a position control system using position and velocity feedback and determine the feedback gains to achieve the given time-domain specifications, build the compensated servo plant in Simulink and simulate offline to obtain the response to a square wave input and verify the design. Use Matlab Simulink for it.

2. **Design of PI Controller for a Heating Control System (HCS)**
   Objective: To design a Integral (I) controller for HCS and plot the closed-loop system response to command and disturbance signals for various values of Ki. Comment upon the effects of increasing Ki on transient response and steady-state error. Through simulations, examine the effect on transient performance when the integral controller is replaced by a PI controller (Kp + Ki/s) with fixed proportional gain Kp = 4. Use Matlab Simulink for it.

3. **Design of a suitable cascade lead, lag, or lag-lead compensator for a given plant**
   Objective: To design a suitable compensator for a given plant to ensure that the damping ratio of the dominant closed loop poles is 0.6 as well as increase the velocity error constant by a factor of 10. Use Matlab Simulink for it.

4. **Design of a Lead compensator in the frequency domain for a given plant.**
   Objective: To design a lead compensator for a given plant such that the following specifications (Acceleration error constant Ka = 10, Phase Margin >=35^0) are satisfied. Use Matlab Simulink for it.

5. **Design of a Lag-Lead compensator in the frequency domain for a given plant.**
   Objective: To design a lead compensator for a given plant such that the following specifications (Velocity error constant Kv = 30, Phase Margin >=50^0, and Bandwidth = 12 rad/sec) are satisfied. Use Matlab Simulink for it.

6. **Design of a State Observer for an undamped oscillator with frequency w_0 for a given plant.**
   Objective: To describe the equations of motion in the state-variable form for the above system and further design a second-order observer that estimates the states given measurements of the position (state x_1) . Use Matlab Simulink for it.

7. **Design of a Observer Based State Feedback (OBSF) system for a given system.**
   Objective: To design a state-feedback gain which places the closed loop characteristic roots at ±j0.5, state-observer which places the characteristic roots at z = 0, and then design OBSF. Use Matlab Simulink for it.

8. **Design of a compensator (D(z)) in the discrete domain using the root-locus method that meets the following specifications.**
   Objective: To design a compensator D(z) in the discrete domain that satisfies the specifications (damping factor = 0.5, Natural Frequency = 1.5, and Kp>=7.5). Use Matlab LTI viewer to determine the peak time and settling time of the closed-loop step response.

9. **Design a controller using root-locus, time domain, frequency domain and state space techniques to control the position of motor using only the position measurement in HILINK platform.**
   Objective: To design a controller (using root-locus, time domain, frequency domain and state space techniques) to control the position of motor using position measurement that satisfies the specifications: settling time<2 sec. and overshoot<10% in its first step (step height of 1 rad) response.

10. **Design a controller using root-locus, time domain, frequency domain and state space techniques to control the speed of motor using only the speed measurement in HILINK platform.**
    Objective: To design a controller (using root-locus, time domain, frequency domain and state space techniques) to control the speed of motor using speed measurement that satisfies the specifications: settling time<2 sec. and overshoot<10% in its first step (step height of 10 rad/s) response.

Books recommended:

Text Books:

1. B.C. Kuo, "Automatic Control System", 7th Edition PHI. (T1)
2. M. Gopal, "Control Systems Principles & Design", 2nd Edition, TMH. (T2)
3. J.G. Truxal, "Automatic Feedback Control System", McGraw Hill, New York. (T3)
4. K. Ogata, "Discrete Time Control Systems", 2nd Edition, Pearson Education. (T4)

Reference Books:

1. Norman Nise, "Control System Engineering", 4th Edition. (R1)
2. M. Gopal, "Digital Control & State Variable Method", TMH. (R2)
3. B.C. Kuo, "Digital Control System", 2nd Edition, Oxford. (R3)
4. Stephanie, “Design of Feedback Control Systems”, 4^{th} Edition, Oxford. (R4)

Course Evaluation:

Individual assignment, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements)

(1) Real time analog design of controllers.
(2) Interfacing the controllers with the real time physical plants to identify the effects on system's performance.

POs met through Gaps in the Syllabus

POs met are:

(c) Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

(d) Recognise the need for continuous learning and will prepare oneself to create, select and apply appropriate techniques and modern engineering and IT tools to solve complex control system problems.

Topics beyond syllabus/Advanced topics/Design

(i) Advanced robust design methods for different control problems

POs met through Topics beyond syllabus/Advanced topics/Design

POs met are:

(d) Recognise the need for continuous learning and will prepare oneself to create, select and apply appropriate techniques and modern engineering and IT tools to solve complex control system problems

Course Delivery methods	
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Mini projects/Projects
CD4	Laboratory experiments/teaching aids
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment (60%)

Assessment Tool		% Contribution during CO Assessment
Progressive Evaluation	Day to Day Performance	30
	Quiz	10
	Viva	20
End Sem Examination Marks	Lab Performance	30
	Quiz	10

Indirect Assessment (40%)

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping of lab experiment with Course Outcomes

Experiment	Course Outcomes				
	1	2	3	4	5
1	H	H	L	L	L
2	H	H	L	L	L
3	H	H	L	L	L
4	H	H	L	L	L
5	H	H	L	L	L
6	H	M	H	M	M
7	H	M	H	M	M
8	H	M	H	H	M
9	H	H	H	H	H
10	H	H	H	H	H

MAPPING BETWEEN COURSE OBJECTIVES AND COURSE OUTCOMES:

	Course Outcomes				
Course Objectives	(i)	(ii)	(iii)	(iv)	(v)
1	H	H	H	L	L
2	H	H	M	M	L
3	H	H	H	M	M
4	H	H	H	H	H

Mapping between course outcomes and program outcomes

COs	a	b	c	d	e	f
1	H	H	M	L	L	L
2	H	H	M	M	M	L
3	H	H	H	H	M	L
4	H	M	M	H	H	M
5	H	H	M	M	H	H

*H: High (0.9), M: Medium (0.7), L: Low(0.4)

Mapping between course outcomes and course delivery method

Course Outcomes	Course Delivery Method
CO1	CD1
CO2	CD1,CD2,CD3,CD6
CO3	CD1,CD2,CD3,CD6
CO4	CD1,CD2,CD3,CD6
CO5	CD1,CD2,CD3,CD6

Course code: EE504
Course title: AI based Advanced Control System Laboratory
Pre-requisite(s): Introduction to System theory, Control theory, Control system design
Co- requisite(s):
Credits: 2 L:0 T:0 P:4
Class schedule per week: 04
Class: M.Tech.
Semester / Level: I/05
Branch: Electrical Engineering
Name of Teacher:

Course Objectives:

This course enables the students to:

1.	To analyse different non-linear systems.
2.	To study adaptive control system and basic of Artificial Intelligence techniques.
3.	To develop identification/equalization/noise cancelation models in time domain and frequency domain.
4.	To simulate and test different adaptive control techniques in health care.
5.	To develop different techniques in image/video processing applications.

Course Outcomes:

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

1.	Analysis of non-linear, time varying and unstable systems.
2.	Study of adaptive control system and artificial intelligence techniques.
3.	Development of different AI based model for identification/equalization/noise cancelation applications.
4.	Investigation of AI based approaches in health care applications.
5.	Development of AI based techniques in image/video processing applications.

Lab Experiments:

1. Analysis of non-linear system.
2. Introduction to adaptive control system.
3. Data prediction of non-linear time series data.
4. Noise cancelation from 1D/2D/3D time series data.
5. Identification of non-linear system.
6. Equalization of non-linear system.
7. Parameter optimization of system/controller.
8. Classification of 1D/2D/3D data.
9. Kalman filter application for prediction/noise suppression/identification/optimization problem.
10. Artificial Intelligence applications to health monitoring.
11. Artificial Intelligence applications to any 1D/ image/ video signal processing.
12. Artificial Intelligence applications to robotics applications.

Books recommended:

Text Books:

1. B.C. Kuo, "Automatic Control System", 7th Edition PHI.
2. M. Gopal, "Control Systems Principles & Design", 2nd Edition, TMH.
3. J.G. Truxal, "Automatic Feedback Control System", McGraw Hill, New York.
4. K. Ogata, "Discrete Time Control Systems", 2nd Edition, Pearson Education.
5. Jang,Sun,Mizutani, “Neuro-Fuzzy and Soft Computing” PHI.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool		% Contribution during CO Assessment
Progressive Evaluation	Day to Day Performance	30
	Quiz	10
	Viva	20
End Sem Examination Marks	Lab Performance	30
	Quiz	10

INDIRECT ASSESSMENT –

1. Student Feedback on Course Outcome

MAPPING OF COURSE OUTCOMES ONTO PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	
CO2	3	3	3	3	2	3
CO3	3	3	3	3	2	
CO4	3	3		3	3	
CO5	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1. Sight (Low) 2. Moderate (Medium) 3. Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

1. Real time implementation of techniques to meet industry requirements

POs met through Gaps in the Syllabus: 1,2,3,4

Topics beyond syllabus/Advanced topics/Design:

Simulation given to students as assignments

POs met through Topics beyond syllabus/Advanced topics/Design:

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Self- learning such as use of NPTEL materials and internets
CD5	Simulation

MAPPING BETWEEN COS AND COURSE DELIVERY (CD) METHODS

Course Outcome	Course Delivery Method
CO1	CD1,CD2,CD4
CO2	CD1,CD2,CD4
CO3	CD1,CD2,CD3,CD4,CD5
CO4	CD1,CD2,CD3,CD4,CD5
CO5	CD1,CD2,CD3,CD4,CD5

COURSE INFORMATION SHEET
(Program Elective C)

Course code: EE566
Course title: Embedded Control of Switching Power Converters
Pre-requisite(s): Power electronics,
Co- requisite(s):
Credits: 03 L:03 T:0 P: 0 C:03
Class schedule per week: 03
Class: M.Tech
Semester / Level: II/05
Branch: EEE
Name of Teacher:

Course Objectives

This course enables the students to:

A.	Understand modeling and control power converters.
B.	Explain of PWM techniques the need for digital control
C.	Analyse of DPWM techniques and its implementation.
D.	Perform evaluation of close loop power converter
E.	Plan and design procedure for a complex power converter- based drives system.

Course Outcomes

After the completion of this course, students will be:

1.	*List the different PWM techniques for control*.
2.	*Associate with the architecture of DPWM*. *Show* suitability of a power converter for a particular application. *Solve* power management related problems with application of power electronics-based topologies.
3.	*Outline* shortcomings of analog PWM. *Identify the potential of DPWM in the control techniques*.
4.	*Estimate* the cost and long-term impact of control of power converters by DPWM on a large scale project of socio-economic importance.

5.	*Modify* existing power converter based. *Design a* new control topology for the control of power converter having superior performance. *Lead* or *support* a team of skilled professionals.

Syllabus

Module 1: [2 L]

Introduction to power converters:

Introduction to switching power converters and emerging applications, such as dynamic voltage scaling, power amplifier, energy harvesting, etc.

Module 2: [10 L]

Modelling and Control in PWM Switching Converters:

Introduction to basic DC-DC converter topologies, such as buck converter, boost converter, buck/boost converters, etc., PWM control techniques such as voltage mode control (VMC), current mode control (CMC); CCM and DCM operating modes, Modelling of PWM DC-DC converters, State-space averaging technique, small-signal modelling, Control challenges, limitations of analog control techniques and need for digital control in DC-DC converters

Module 3: [10 L]

Digital Pulse Width Modulator (DPWM) Architecture and analysis:

DPWM architectures in DC-DC converters: Counter-based DPWM, tapped-delay line based DPWM, hybrid DPWM, segmented DPWM, Frequency domain analysis of digitally controlled DC-DC converters, special emphasis on effects of finite sampling and quantization, such as limit cycle oscillations, Discrete-time modelling and analysis for existence of sub-harmonic oscillations in DPWM DC-DC converters

Module 4: [10 L]

Compensation Techniques in digitally controlled DC-DC converters:

Discrete-time compensation techniques in digitally voltage mode control, current mode control, and state-feedback control; Deadbeat control; Critical bandwidth formulation, compensator design for non-minimum phase converters, Auto-tuning in digitally controlled DC-DC converters such as Ziegler-Nichols tuning, relay-based tuning etc

Module 5: [8L]

Non- linear control and embedded control implementation:

Sliding mode control in DC- DC converters, Time optimal control and physical limits in DC- DC converters. Introduction to Verilog HDL, Signal conditioning circuits: Selection of ADCs and DACs

Text Books (T):

- P.T. Krein, Elements of Power Electronics. New York: Oxford Univ. Press, 1998.
- R.W.Erickson and D. Maksimovic, Fundamentals of Power Electronics, 2nd ed. Dordrecht, The Netherlands: Kluwer, 2001.

- S. Banerjee and G. C. Verghese, Eds., Nonlinear Phenomenon Power Electronics: Attractors, Bifurcations, Chaos, and Nonlinear Control,New York: IEEE Press, 2001.
- F. Maloberti, “Data Converters”, Springer, 2007
- Michael D. Ciletti, “Modeling, synthesis, and rapid prototyping with the Verilog HDL”, Prentice Hall, 1999.
- V. Bobal, J.Bohm, and J.Fessl,“Digital Self-Tuning Controllers: Algorithms, Implementation and Applications”1 st Ed.,Springer,2005.
- Francesco Vasca, Luigi Iannell i,Eds,“Dynamics and Control of Switched Electronic Systems:Advanced Perspectives for Modeling, Simulation and Control of Power Converters”, Springer,1st Ed.,2012

Reference Books (R):

- Fundamental of Electrical Drives: G K Dubey
- Electric Motor Drives, modelling analysis and control: R Krishnan
- Power Electronics: Circuits, Devices, and Applications: M H. Rashid

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar	10
Teacher’s Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students’ Feedback on Course Outcome

<u>Mapping Between Course Outcomes and Program Outcomes</u>

CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	2	2	2	1
CO2	3	3	3	3	2	2

C03	3	3	3	3	3	2
CO4	3	3	3	3	3	3
CO5	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements)

Controller implementation using fixed point arithmetic

POs met through Gaps in the Syllabus: PO5

Topics beyond syllabus/Advanced topics/Design

VHDL programming and FPGA based Prototyping

POs met through Topics beyond syllabus/Advanced topics/Design: PO5

Course Delivery methods

CD	**Course Delivery methods**
CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Mini projects/Projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of NPTEL materials and internets
CD9	Simulation

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD6
CO2	CD1, CD6, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD5, CD7

COURSE INFORMATION SHEET

(Program Elective C)

Course code: EE543
Course title: Switched Mode Power Conversion
Prerequisite (s): Power electronics,
Co- requisite (s): Network Theory
Credits: 03 L: 03 T: 0 P: 0 C: 03
Class schedule per week: 03
Class: M.Tech
Semester / Level: II/05
Branch: EEE
Name of Teacher:

Course Objectives
This course enables the students to:

A.	Understand the design of reactive components for power converters.
B.	Understand the design of basic non-isolated converters
C.	Under the operation of isolated converters for EV applications
D.	Design the closed loop control structure of DC-DC converters
E.	Understand the soft switching operation of converters

Course Outcomes
After the completion of this course, students will be:

1.	*Design of power electronics components*
2.	*Design and implementation of non-isolated DC-DC converters*
3.	*Design and operation of isolated DC-DC converters for EV applications*
4.	*Modeling and control structure of various DC-DC converters in both CCM and DCM*
5.	*Soft switching operation of resonant converters*

Syllabus

Module 1:
Introduction: Reactive Elements in Power Electronic Systems, Issues related to switches, Energy storage-capacitor and inductor, Design of inductor, transformer, and capacitors for power electronic applications, DC-DC linear regulators [8 L]

Module 2:
Non-isolated converters: DC steady-state principles, Primitive converters, Three basic switched mode power converter, Operating principles, selection of power switches, Continuous and discontinuous conduction modes, High gain boost converter [8L]

Module 3:
Isolated Converters: Forward converter with waveforms and governing equations, Push pull converter, Half-bridge and full-bridge converter, Fly back converter, Isolated cuk converter [8L]

Module 4:
Modeling and Control of Converters: Modeling of DC-DC converters, state space representation, Circuit averaging, Controller design techniques, PID controller, Voltage and current control, Design of feedback compensators, unity power factor rectifiers, resistor emulation principle and applications to rectifiers [8L]

Module 5:
Resonant Converters: Classification of resonant converters, Basic resonant circuit concepts, Load resonant converters, Quasi-resonant switch converters, Class-E resonant converter, Soft switching in converters, Zero voltage switching, Zero current switching [8L]

Text Books (T):

1. Umanand, L., 2009. *Power Electronics: Essentials and Applications*. Wiley India Pvt. Limited.
2. Krein, P.T., 1998. *Elements of power electronics* (Vol. 126). New York: Oxford University Press.

Reference Books (R):

1. Batarseh, I., 2004. *Power electronic circuits*. John Wiley.
2. Wu, K.C., 2005. *Switch-mode power converters: Design and analysis*. Elsevier.

COURSE INFORMATION SHEET

(Program Elective C)

Course code: EE577
Course title: Control of Electric Drives
Pre-requisite(s): Soft Computing
Co- requisite(s):
Credits: L:3 T: 0 P:0
Class schedule per week: 03
Class: M.E.
Semester/Level:03
Branch: EEE
Name of Teacher:

Course Objectives

This course enables the students:

A.	To remember the basic principles behind soft computing algorithms
B.	To apply intelligent controllers for speed control of motors.
C.	To analyze the performance of adaptive controllers.
D.	To develop intelligent controllers based large-scale plants.
E.	To create an autonomous system requiring interdisciplinary skill.

Course Outcomes

After the completion of this course, students will:

1.	Remember basic algorithms of intelligent controllers such as Neural Network based controllers, fuzzy logic based controllers etc.
2.	Apply intelligent controllers for adaptive electrical drives.
3.	Analyse the performance of intelligent controller based electrical drive-in order to provide cost effective solutions for complex engineering problems which are cost effective.
4.	Predict the potential area of application for intelligent controller for societal benefit
5.	Design intelligent controller-based plant and lead a team of technically skilled people for installation of such controllers.

Syllabus

Module 1: Introduction:

Introduction to non-linearities of an electric machine; Parameter sensitivity in an electrical machine; Need of adaptive control in the electric machine; Effectiveness of adaptive controller in the context of time-variant parameters. Different Paradigms of AI [9L]

Module 2: Artificial Neural Network:

Block diagram of controller design using ANN, Morden reference adaptive system (MRAS), Supervised learning, Unsupervised learning, Supervised learning, Reinforcement learning, ANN based DC motor control, ANN based V/F control of induction motor, ANN based vector control, d-q model of induction machine, ANN based speed and torque control of induction motor. [9L]

Module 3: Fuzzy Based Electric motor drive

Introduction to fuzzy sets, Membership function generation using Genetic Algorithm, Determination of ruled base for speed control, De-fuzzification method, Min-max method, Average method, Centroid method, Fuzzy control of DC motor, Fuzzy control of AC motor, Fuzzy control of BLDC motor.

Module 4: ANFIS Based Adaptive Controls

Introduction to ANFIS, Application of ANFIS for DC motor, Application of ANFIS for scalar control for IM, Application of ANFIS for vector control for IM, Application of ANFIS for BLDC motor. MATLAB Based implementation of ANFIS based control. [9]

Module 5: Deep Learning Integrated Model Predictive Control of Motors

Discrete-Time MPC with Constraints, Development of MPC for BLDC motor, Prediction Control with optimization, Receding Horizon Control, Deep Learning (DL) Algorithms, Introduction to the different architecture of Recursive Neural Network, DL based state estimation in BLDC motor Drive, Stability analysis. [9]

Text book:

"Neural Networks and Fuzzy Systems: A Dynamical Systems Approach to Machine Intelligence/Book and Disk" by Bart Kosko, Prentice Hall.

"Modern Power Electronics & Drives" by B K Bose

"Model Predictive Control System Design and Implementation Using MATLAB" by Liuping Wang, Springer.

Reference Books:

"Fuzzy Logic with Engineering Applications" by Timothy J Ross, 3rd Edition, Wiley

"Kalman Filtering and Neural Network" by Simon Haykin, Wiley Series

Gaps in the syllabus (to meet Industry/Profession requirements) Hardware based project using intelligent controller

POs met through Gaps in the Syllabus

PO5

Topics beyond syllabus/Advanced topics/Design

Assignment: Hardware based project using intelligent controller

POs met through Topics beyond syllabus/Advanced topics/Design

PO5

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/ Projects
Laboratory experiments/teaching aids
Industrial/ guest lectures
Industrial visits/in-plant training
Self-learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Mid Sem Examination Marks	25
End Sem Examination Marks	60
Assignment / Quiz (s)	15

Assessment Components	CO1	C02	C03	C04	CO5
Mid Sem Examination Marks					
End Sem Examination Marks					
Assignment					

Indirect Assessment-

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	PO1	PO2	PO3	PO4	PO5	PO6
1	3	3	3	2	2	1
2	3	3	3	3	2	2
3	3	3	3	3	2	2
4	3	3	3	3	3	2
5	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Mapping Between COs and Course Delivery (CD) methods				
CD	**Course Delivery methods**		**Course Outcome**	**Course Delivery Method**
CD 1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1
CD 2	Tutorials/Assignments		CO2	CD1

CD 3	Seminars		CO3	CD1 and CD2
CD 4	Mini projects/ Projects			
CD 5	Laboratory experiments/teaching aids			
CD 6	Industrial/ guest lectures			
CD 7	Industrial visits/in-plant training			
CD 8	Self-learning such as use of NPTEL materials and internets			
CD 9	Simulation			

Lecture wise Lesson Planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	Cos mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1			1		T1, R1	1, 2		PPT Digi Class/Chalk -Board	
			Introduction					Chalk — board	
	L1-L2			Introduction to non-linearities of electric machine	T2			Chalk — board	
	L3			Parameter sensitivity in electrical machine	T2			Chalk — board	
	L4			Need of adaptive control in electric machine	T2			Chalk — board	
			Artificial Neural Network					Chalk — board	
	L5			Block diagram of controller design using ANN	T1			Chalk — board	
	L6-L9			Morden reference adaptive system (MRAS).	T1, T2			Chalk — board	
	L10			Feed forward network.	T1			Chalk — board	

	L11			Multilayer perceptron model.	T1			Chalk board	—	
	L12			Activation function.	T1			Chalk board	—	
	L13			Supervised learning	T1			Chalk board	—	
	L14			Unsupervised learning	T1			Chalk board	—	
	L15			Supervised learning	T1			Chalk board	—	
	L16			Reinforcement learning.	T1			Chalk board	—	
	L17			Back Propagation algorithm.	T1			Chalk board	—	
	L18			Back Propagation neural architecture.	T1			Chalk board	—	
	L19			K-means learning	T1			Chalk board	—	
	L20			Back propagation training	T1			Chalk board	—	
	L21-L22			ANN based DC motor control.	T1, T2			Chalk board	—	
	L23-L25			ANN based V/F control of induction motor.	T1, T2			Chalk board	—	
	L26			ANN based vector control.	T1, T2			Chalk board	—	
	L27-L30			d-q model of induction machine	T12, T1			Chalk board	—	
	L31-L32			ANN based speed and torque control of induction motor.	T2, T1			Chalk board	—	
								Chalk board	—	
			Fuzzy Based Electric motor drive					Chalk board	—	
	L33			Membership function generation using probability distribution function method.	R1			Chalk board	—	

	L34			Membership function generation using Genetic Algorithm.	R1			Chalk board —	
	L35-L36			Determination of ruled based for speed control.	R1			Chalk board —	
	L37			Fuzzy control of DC motor.	R1			Chalk board —	
	L38			Fuzzy control of AC motor.	R1				
	L39			Fuzzy control of BLDC motor.	R1				
	L40			Introduction to ANFIS.	T1, R1			Chalk board —	
	L41			Application of ANFIS for DC motor.	T1, R1			Chalk board —	
	L42			Application of ANFIS for scalar control for IM	T1, R1			Chalk board —	
	L43			Application of ANFIS for vector control for IM.	T1, R1			Chalk board —	
	L44			Application of ANFIS for BLDC motor.	T1, R1			Chalk board —	
			Deep Learning Integrated Model Predictive Control of Motors					Chalk board —	
	L45			Discrete-Time MPC with Constraints	R2			Chalk board —	
	L46			Development of State space model for discrete MPC	R2			Chalk board —	
	L47			Receding Horizon Control				Chalk board —	
	L48			Deep Learning based state estimation in BLDC motor				Chalk board —	
	L49			Stability Analysis				Chalk board —	

COURSE INFORMATION SHEET

(Program Elective C)

Course code: EE569
Course title: Electric Vehicles
Pre-requisite(s): Power electronics
Co- requisite(s):
Credits: 03 L:03 T:0 P:0 C:03
Class schedule per week: 03
Class: M.Tech
Semester / Level: 11/05
Branch: EEE
Name of Teacher:

Course Objectives

This course enables the students to:

A.	Understand working of Electric Vehicles.
B.	Able to choose components for a given electrical vehicle design and dimension them according to the specification.
c.	To integrate electrical vehicle components into a system and design for necessary controls.
D.	To estimate and understand the requirement for the infrastructure, including various charging and power distribution solutions, required for electrical vehicles
E.	To evaluate an electrical vehicle design and infrastructure using modern tools.

Course Outcomes

After the completion of this course, students will be:

1.	List the different types of EVs
2.	Associate with the different architecture of EVs. Show suitability of a power converter in the EVs.
3.	Determine the rating of energy source requirement of EV

4.	Estimate the cost and long-term impact of control of power converters by DPWM on a large scale project of socio-economic importance.
5.	Modify existing EV architectural design. Design a new efficient EV having superior performance.

Syllabus

Module 1:

Introduction to Electric Vehicles: Evolution of Electric Vehicles, Electric Vehicles and the Environment, EV classification and comparison with internal combustion engine: Technology, Advantages and Disadvantages of EV, EV configurations, Parameters of EV systems [4L]

Module 2:

Electric Machines in EV:

Working principle of DC machines, characteristics and types of DC machines, Overview of (speed torque characteristics) permanent magnet motor, BLDC motor, Electrical motor topologies and operations principles: radial, axial and transversal flux motors. Torque production and characteristics of induction, permanent magnet and reluctance motors, comparison of all motors' performance in EV [10L]

Module 3:

Converters in Electric vehicles

AC-DC and DC- DC converters, Inverters, Soft switching topologies for EV, Isolated Bidirectional converters in EV. [10L]

Module 4:

Energy storage for EV:

Energy storage requirements, Battery parameters, types of batteries, modelling of battery, SOC and depth of discharge of battery in EV, Electrical Design considerations of EV [10L]

Module 5:

Charging Infrastructures:

Introduction, Understanding charging economics, commercial charging and pricing models, Load managements for large scale EV integration [12L]

Text Books (T):

1. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003
2. C. C. Chan, K. T. Chau: Modern Electric Vehicle Technology, Oxford University Press Inc., New York 2001

Reference Books (R):

1. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design M. Ehsani, Y. Gao, S. Gay and Ali Emadi CRC Press 2005
2. Electric and Hybrid Vehicles: Design Fundamentals Iqbal Husain CRC Press 2003

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT -

1. Students' Feedback on Course Outcome

<u>Mapping Between Course Outcomes and Program Outcomes</u>

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	2	2	1
CO2	3	3	3	3	2	2
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	3

CO5	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements) Controller implementation using fixed point arithmetic

POs met through Gaps in the Syllabus: PO5

Topics beyond syllabus/Advanced topics/Design

Design of battery charging infrastructure

POs met through Topics beyond syllabus/Advanced topics/Design: PO5

Course Delivery methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Mini projects/Projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of NPTEL materials and internets
CD9	Simulation

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD6
CO2	CD1, CD6, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD5, CD7

Course code: EE583R1
Course title: Renewable Sources of Electrical Energy and Grid Integration
Pre-requisite(s): Power Electronics and Power System
Co- requisite(s):
Credits: 03 L: 03 T: 0 P: 0 C: 03
Class schedule per week: 03
Class: M.Tech
Semester / Level: II/05
Branch: EEE
Name of Teacher:

Course Objectives:
This course enables the students to:

A	Understand about different sources of energy
B	Analyze maximum generation from SPV, and its integration with Grid
C	Develop a model about wind generation, wind generators and control.
D	Carry out design work on different other issues like battery management, reactive power,harmonic mitigation.
E	Evaluate cost and efficiency of grid integrated system.

Course Outcomes:
Upon completion of the course, student will be able to:

1	Articulate the basic operation of different renewable sources and storage method of electrical energy
2	Develop the mathematical modelling of SPV with controllers and design the controllers.
3	Explain mathematical modelling of Wind turbine system and devise the controllers.
4	Carry out the designing power converters and controllers in grid interactive mode.
5	Apply themselves for solving different issues like reactive power, harmonic, etc.

Syllabus:

Module I: Drivers of Renewable sources of electrical energy
Decarburization, Energy security, Expanding energy access, Present status of RE generation and future projections, Wind energy, Solar energy, RE grid integration challenges, Non- controllable variability, Partial unpredictability, Locational dependency [4L]

Module II: Basics of solar PV
Solar PV systems: Fundamentals of solar cell, semiconductors as basis for solar cells materials and properties, P-N junction, sources of losses and prevention, I-V and P-V characteristics, Array design [4L]

Module III: Power converters and control for PV
Characteristics and circuit models, Topologies, principles of operation. Maximum power tracking algorithms and Buck-Boost Converter, single- and three-phase inverters for PV , PLL technique for grid interfacing, Harmonic analysis, power quality and filter design, Current injection control at unity power factor, reactive power control and smart inverters, interconnection standards such as IEEE 1547, Steady-state and dynamic models of PV systems and implementation in simulation tools [15L]

Module IV: Wind Energy: Power converters and control for wind generators
Overview of wind turbine systems and configurations, Detailed analysis of doubly fed induction generator and PMSM based wind generators ,Dynamic modelling of wind generators, Field oriented control of rotor side and grid side power converters , Control methods for maximum power extraction, active and reactive power control [12L]

Module V: Basics of other renewable sources
Biomass Energy System: Biomass – various resources, energy contents, technological advancements, Hydro energy: Feasibility of small, mini and micro hydel plants scheme, Tidal and wave energy, Fuel Cell, Energy storage: Battery – types, equivalent circuit, performance characteristics, battery design, charging and charge regulators. Battery management, Ultra Capacitors. [5L]

Text Books:
1. Renewable energy technologies - R. Ramesh, Narosa Publication.
2. Energy Technology – S. Rao, Parulkar 3. Non-conventional Energy Systems – Mittal, Wheelers Publication.

Reference Books:
1. Wind and solar systems by Mukund Patel, CRC Press.
2. Solar Photovoltaics for terrestrials, Tapan Bhattacharya.
3. Wind Energy Technology – Njenkins, John Wiley & Sons
4. Solar & Wind energy Technologies – McNeils, Frenkel, Desai, Wiley Eastern.
5. Solar Energy – S.P. Sukhatme, Tata McGraw Hill.
6. Solar Energy – S. Bandopadhay, Universal Publishing.
7. Guide book for National Certification Examination for EM/EA – Book 1

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

Students' Feedback on Course Outcome

Mapping between CO and PO

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	2
CO2	3	3	3	3	2	2
CO3	3	3	3	2	3	2
CO4	3	3	3	2	2	3
CO5	3	3	2	2	2	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements): Different Standards and technical guidelines of RES operation and integration.

POs met through Gaps in the Syllabus: Part of PO5.

Topics beyond syllabus/Advanced topics/Design: Guidelines, MATLAB simulation

POs met through Topics beyond syllabus/Advanced topics/Design: Part of PO4 and PO5.

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	Self- learning such as use of NPTEL materials and internets
CD6	Simulation

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3,CD5
CO2	CD1, CD2, CD3,CD5
CO3	CD1, CD2, CD3,CD5
CO4	CD1, CD2, CD3,CD5
CO5	CD1, CD2, CD3,CD5

Course code: EE547

Course title: Battery Management System
Pre-requisite(s): Power electronics, Chemistry Co- requisite(s):
Credits: 03 L:03 T:0 P:0 C:03
Class schedule per week: 03
Class: M.Tech
Semester / Level: 11/05
Branch: EEE
Name of Teacher:

Course Objectives

This course enables the students to:

A.	Understand basic nomenclature of battery parameters.
B.	Interpret correlation between chemical dynamics and electrical potential.
C.	Compute SoC and SoH.
D.	Perform evaluation of functionalities of BMS.
E.	Plan and design procedure for cost-effective design of battery management system.

Course Outcomes

After the completion of this course, students will be able to:

1.	Explain different battery parameters
2.	Analyze electrochemical dynamics in order to correlate electrochemical parameters with health and ageing of the battery various
3.	Apply state of art methods for cell balancing and computing SoC.
4.	Estimate the cost and effectiveness of BMS system.
5.	Design the power converter BMS for a battery pack

Syllabus
Module 1:

Introduction:

Introduction to Battery Management System, Cells & Batteries, Nominal voltage and capacity, C rate, Energy and power, Balancing issues in Cells connected in series and Cells connected in parallel, Electrochemical Dynamics of lithium-ion cells, Safe Operating area, Charging and Discharging Process, Efficiency, Ageing, Modes of Charging [8L]

Module 2:

Battery Management System Requirement:

Introduction and BMS functionality, Battery pack topology, BMS Functionality, Voltage Sensing, Temperature Sensing, Current Sensing, BMS Functionality, High-voltage contactor control, Isolation sensing, Thermal control, Protection, Communication Interface, Range estimation, State-of charge estimation, Cell total energy, and cell total power [10]

Module 3:

Battery State of Charge and State of Health Estimation, Cell Balancing:

Battery state of charge estimation (SOC), voltage-based methods to estimate SOC, Model based state estimation, Battery Health Estimation, Lithium-ion aging: Negative electrode, Lithium-ion aging: Positive electrode, Cell Balancing, causes of imbalance, Cell balancing topology [10L]

Module 4:

Modeling and Simulation:

Equivalent-circuit models (ECMs), Physics-based models (PBMs), Empirical modelling approach, Physics-based modeling approach, Simulating an electric vehicle, Vehicle range calculations, Simulating constant power and voltage, Simulating battery packs. [10L]

Module 5:

Design Methodology:

State of Art for cell balancing, Condition Monitoring, Thermal management, Protection, Communication Protocols, Application of IOT, Power Converter Design for parallel distribution of charges. [10L]

Text Books (T):

1. Plett, Gregory L. Battery management systems, Volume I: Battery modeling. Artech House, 2015.
2. Plett, Gregory L. Battery management systems, Volume Il: Equivalent-circuit methods. Artech House, 2015.

Reference Books (R):

1. Bergveld, H.J., Kruijt, W.S., Notten, P.H.L "Battery Management Systems -Design by Modelling" Philips Research Book Series 2002.

2. Davide Andrea," Battery Management Systems for Large Lithium-ion Battery Packs" Artech House, 2010
3. Pop, Valer, et al. Battery management systems: Accurate state-of-charge indication for battery-powered applications. Vol. 9. Springer Science & Business Media, 2008.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT -

1. Students' Feedback on Course Outcome

Mapping Between Course Outcomes and Program Outcomes

CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	2	2	2	1
CO2	3	3	3	3	2	2
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	3
CO5	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements) Adaptive control for BMS

POs met through Gaps in the Syllabus: PO5

<u>Topics beyond syllabus/Advanced topics/Design</u>

Model Predictive Controller Design for BMS

<u>POs met through Topics beyond syllabus/Advanced topics/Design</u>: PO5

Course Delivery methods

CD	**Course Delivery methods**
CD1	Lecture bu use of boards LCD projectors/ OHP projectors
CD2	Tutorials Assignments
CD3	Seminars
CD4	Mini projects/ Projects
CD5	Laboratory experiments teaching aids
CD6	Industrial/ guest lectures
CD7	Industrial visits/ in- plant training
CD8	Self- learning such as use of NPTEL materials and internets
CD9	Simulation

<u>Mapping between Course Outcomes and Course Delivery Method</u>

Course Outcomes	Course Delivery Method
CO1	CD1, CD6
CO2	CD1, CD6, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD5, CD7

Course code: EE621R1
Course title: Power Quality and Control
Pre-requisite(s): Power System, Power Electronics, Renewables
Credits: 03 L:3 T:0 P:0 C: 03
Class schedule per week: 03
Class: M.Tech.
Semester / Level: II/02

Course Objectives:

A.	Enumerate different standards of common power quality phenomena.
B.	Understand power quality monitoring and classification techniques.
C.	Investigate different power quality phenomena causes and effects.
D.	Understand different techniques for power quality problems mitigation.

Course Outcomes:

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

1.	Outline the various power quality phenomenon's, their origin and monitoring.
2.	Analyze the significance of transient over voltages, their origin and mitigation methods.
3.	Study the impact of harmonic distortion and mitigation methods through filter design.
4.	Understand the voltage regulation methods with distributed resources.
5.	Assess and integrate power quality issues for microgrids with distributed energy resources.

Syllabus

Module-I

Introduction–Overview of power quality, Power quality: concepts and definition, Power quality and voltage quality, International power quality standards, and regulations, General classes of power quality problems, CBEMA and ITI Curves, Power quality terms, Power frequency variations, Concern about the power quality, EMC standard. [8L]

Module-II

Loads which causes power quality problems, Long-duration voltage variations, Short-duration voltage variations, Voltage imbalance, Waveform distortion, Voltage sags and interruptions, sources of sags and interruptions, Estimating voltage sag performance, Sensitivity of equipment to voltage sag. Transient over voltages – Source of transient over voltages, power quality monitoring [8L]

Module-III

Power system harmonics: Harmonics, Inter-harmonics, Intra-harmonics, Sub-harmonics, Difference between harmonics and transients, Voltage and current distortion, Harmonic indices and standards, Sources of harmonic distortion, Effects of harmonic distortion, Mitigation and control techniques, Harmonic filters. [8L]

Module-IV

Transients: origin and classifications, Capacitor switching transient, Lightning-load switching, Non-linear device switching, Impact on users, Protection, Mitigation. [8L]

Module-V

Power factor correction, Zero voltage regulation, Reactive power compensation, Load balancing using load compensation techniques: active and passive shunt/series compensation, DSTATCOM (Distribution Static Compensators), DVR (Dynamic Voltage Restorers), UPQC (Universal Power Quality Conditioners [8L]

Textbooks and References

1. Surya Santoso, H. Wayne Beaty, Roger C. Dugan, Mark F. McGranaghan, "Electrical Power Systems Quality", McGraw-Hill, 2002.
2. Bollen, M.H.J, "Understanding Power Quality Problems: Voltage sags and interruptions", IEEE Press, New York, 2000.
3. C. Sankaran, "Power Quality" CRC Press
4. Arindam Ghosh, Gerard Ledwich, "Power quality enhancement using custom power devices", Springer, 2002.
5. Angelo B. Baggini, "Handbook of power quality", Wiley, 2008
6. Arrillaga, J, Watson, N.R., Chen, S., "Power System Quality Assessment", Wiley, New York, 2000

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT -

1. Students' Feedback on Course Outcome

<u>Mapping Between Course Outcomes and Program Outcomes</u>

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	2	2	1
CO2	3	3	3	3	2	2
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	3
CO5	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

<u>Gaps in the syllabus (to meet Industry/Profession requirements)</u> Adaptive control for BMS

<u>POs met through Gaps in the Syllabus</u>: PO5

<u>Topics beyond syllabus/Advanced topics/Design</u>

Model Predictive Controller Design for BMS

<u>POs met through Topics beyond syllabus/Advanced topics/Design</u>: PO5

Course Delivery methods

CD	Course Delivery methods
CD1	Lecture bu use of boards LCD projectors/ OHP projectors
CD2	Tutorials Assignments
CD3	Seminars
CD4	Mini projects/ Projects
CD5	Laboratory experiments teaching aids
CD6	Industrial/ guest lectures
CD7	Industrial visits/ in- plant training
CD8	Self- learning such as use of NPTEL materials and internets
CD9	Simulation

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD6
CO2	CD1, CD6, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD5, CD7

Course code: EE579
Course title: Industrial Instrumentation and Control
Pre-requisites: Electrical Measurement and Instrumentation
Co-requisites:
Credits: L:3 T:0 P:0
Class schedule per week: 03
Class: MTech
Semester/Level: II
Branch: Control/ EEE
Name of Teacher:

Course objectives

This course aims to provide the students with adequate knowledge about:

A.	The control strategies used in industrial instrumentation systems.
B.	The operating principles of sensors and systems used for the measurement of physical variables such as force, torque, velocity, pressure, flow, level, etc.
C.	Application aspects of sensors and measurement systems used in professional practice, specifically in industrial automation.
D.	Sensor signal conditioning, Data transmission techniques, selection criteria.

Course Outcomes

After the completion of this course, students will be able to:

1.	Understand the basics of industrial instrumentation and signal transmission techniques used in an instrumentation system.
2.	Impart knowledge about the static and response characteristics of first order and higher order measurement system.
3.	Understand the control mechanisms in an instrumentation system.
4.	Acquire knowledge about transmitters and understand the working of flow meters and level measurement systems.
5.	Understand the calibration, installation, and other aspects of pressure measurement. Learn about the digital and smart transmitters used in industries.

Syllabus

Module 1 **Lecture hours: 8**

Industrial Instrumentation systems: Types of industrial variables and measurement systems elements - sensors and transducers for different industrial variables like pressure, level, flow, etc. Sensor scaling. Industrial signal conditioning systems: Amplifiers, Filters, A/D converters for industrial measurements. Basics of Data transmission: IEEE-488 bus, RS 232 and RS 485 interface. HART protocol.

Module II **Lecture hours: 8**

Calibration and response of Industrial Instrumentation: Standard testing methods and procedures, performance characteristics, response characterization — static and dynamic, response to different forcing functions.

Module III **Lecture hours: 8**

Control System Instrumentation: Transducers, Transmitters, Final control elements, Schemes, and analysis of typical process control strategies: Feedforward control, Ratio control, Cascade control, Split-Range control.

Module IV **Lecture hours: 8**

Displacement and proximity gauges. Introduction to electronic transmitters. Pneumatic and Hydraulic Instrumentation system. Limit switch, Proximity Sensors. Flow measurement: Flowmeter. Criteria for selection of flowmeters. Measurement of Level: Point level measurement, Continuous level measurement.

Module V **Lecture hours: 8**

Measurement of Pressure. Actuator and Electronic pressure transmitters. Calibration, installation, signal processing and control of pressure measuring devices. Measurement accessories. Smart, Intelligent transmitters - features & advantages. IOT Transmitters.

Textbooks

1. Principles of Industrial Instrumentation, D. Patranabis, Tata McGraw Hill.
2. Instrumentation and Control, D. Patranabis, PHI.
3. Measurement Systems Application and Design, E.O. Doebelin, Tata McGraw Hill.
4. Fundamentals of Industrial Instrumentation, Alok Barua, Wiley.
5. Measurement & Instrumentation: Trends & Applications, M.K. Ghosh, S. Sen, and S. Mukhopadhyay.

Reference books

1. Liptak B.G, Instrumentation Engineers Handbook (Measurement), Chilton Book Co.,
2. John G Webster, Measurement, Instrumentation and Sensors, Handbook, CRC Press.
3. Principles of Measurement, John Bentley, Pearson.
4. Measurement and Instrumentation Principles, A. S. Morris, Butterworth-Heinemann.
5. Industrial Instrumentation, K. Krishnaswamy, New Age International Publishers, New Delhi.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT -

1. Students' Feedback on Course Outcome

Mapping Between Course Outcomes and Program Outcomes

CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	2	2	2	1
CO2	3	3	3	3	2	2
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	3
CO5	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements) Adaptive control for BMS

POs met through Gaps in the Syllabus: PO5

Topics beyond syllabus/Advanced topics/Design

Model Predictive Controller Design for BMS

POs met through Topics beyond syllabus/Advanced topics/Design: PO5

Course Delivery methods

CD	**Course Delivery methods**
CD1	Lecture bu use of boards LCD projectors/ OHP projectors
CD2	Tutorials Assignments
CD3	Seminars
CD4	Mini projects/ Projects
CD5	Laboratory experiments teaching aids
CD6	Industrial/ guest lectures
CD7	Industrial visits/ in- plant training
CD8	Self- learning such as use of NPTEL materials and internets
CD9	Simulation

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD6
CO2	CD1, CD6, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD5, CD7

Course Code: EE572
Course title: Power Converter Design Laboratory
Credits: 02 L: 0 T:0 P: 04 C: 02
Class schedule per week: 4 Class: M.Tech.
Semester / Level: III/06 Branch: Electrical Engineering
Name of Teacher:
Class schedule per week: 4
Course Objectives:
This course enables the students to:

A	List different Real Time processors required for power electronics and drives application.
B	Mathematical model different converters.
C	Analyze simulation models in the field of electrical drives, power conversion and transmission.
D	Evaluate accuracy of simulation-based systems as compared to real-system
E	Design hardware model of complex systems and lead a team of experts in power electronics and electrical drives system.

Course Outcomes:
After the completion of this course, students should be able to:

CO1.	List different DSPACE and OPALRT blocks required for power electronics and drives simulation as well as control.
CO2	Develop State Space Model of power converters.
CO3.	Analyze simulation models for evaluating dynamic performance parameters.
CO4	Evaluate accuracy of simulation-based systems as compared to hardware-based prototype.
CO5	Design hardware based complex systems and lead a team of experts in power electronics and electrical drives system.

LIST OF EXPERIMENTS:

1. Name: Mathematical modelling of a Boost Converter and controller design.
 Aim: (a) To develop state space model in DCM and CCM
 (b) Obtain controller gains for obtaining particular time domain specifications.
2. Name: Simulate the closed loop control of Boost Converter with computed controller gains.

Aim: (a) Simulate developed State Space model to find step response

(b) Obtain frequency domain response using MATLAB

3. Name: Develop the firing circuit and power circuit of Boost Converter

Aim: (a) Design optically isolated firing circuit for Boost converter on a varo-board.

(b) Design power circuit on a varo-board using Power MOSFET

4. Name: Conduct experiment on hardware model of Boost converter to obtain efficiency vs duty cycle curve.

Aim: (a) Determine boost factor vs duty cycle curve

(b) Observe dynamic parameters in the time domain and compare it with simulated result.

5. Name: Mathematical computation for filter design of a 3 Phase voltage source inverter.

Aim: (a) Obtain Fourier transform of Line voltage and phase voltage waveform.

(b) Compute the value of the inductor and capacitor for filter design.

6. Name: Simulate 3 Phase VSI with filter and obtain filter response in terms of improvement in THD

Aim: (a) Simulate 3 Phase VSI without and with filter and obtain THD in each case.

(b) Implement Selected harmonics elimination based PWM technique in the MATLAB environment.

7. Name: Design firing circuit of 3 phase VSI.

Aim: (a) Develop hardware model of firing circuit for 3 Phase VSI

(b) Interface Microcontroller and Gate terminal of Switches with correct biasing.

8. Name: Design Power Circuit of a 3 phase VSI

Aim: (a) Develop three phase VSI hardware on varo-board

(b) Design hardware of filter circuit

9. Name: Perform experiment on 3 phase VSI.

Aim: (a) Obtain MI vs RMS line voltage

(b) Obtain THD vs Carrier Frequency curve

10 Name: Simulate and obtain response of a CUK regulator.

Aim: (a) develop output voltage and output current expression.

(b) Verify Input and Output voltage and current waveform using MATLAB based Simulink.

Text Books:

1. P.S. Bimbra, Generalised Theory of Electric Machines, Khanna Publications, 7th Edition, Delhi, 2010
2. M.H. Rashid, Power Electronics, PHI,

Reference Books:

1. B K Bose: Modern Power Electronics and A C Drives, PHI , Delhi
2. G K Dubey, Fundamental of Electric Drives, 2nd Edition, PHI, Delhi.
3. C.M. Ong, Dynamic Simulation of Electric Machinery, PH, NJ.

Mapping of Course Outcomes onto Program Outcomes

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	1	3	2	1
CO2	3	3	3	3	2	2	3	2	2
C03	3	3	3	3	3	2	3	3	2
CO4	3	3	3	3	3	3	3	3	3
CO5	3	3	3	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

1. Design of real-time industrial projects.

POs met through Gaps in the Syllabus PO6

Topics beyond syllabus/Advanced topics/Design

Group assignments on practical use of power electronics in industry.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT:

Assessment Tool	% Contribution during CO Assessment
Progressive Evaluation: Lab Quiz (1)	1x10 = 10
Progressive Evaluation: Daily Evaluation	30
Progressive Evaluation: Viva	20
End Semester Evaluation: Experiment Performance	30
End Semester Evaluation: Lab Quiz (1)	10

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1, CD6
CO2	CD1, CD6, CD7
CO3	CD1, CD2, CD3, CD6,CD7
CO4	CD1, CD3, CD6,CD7
CO5	CD1,CD2,CD3,CD4,CD5,CD7

Course code: EE574
Course title: Electric Drive Lab
Pre-requisite(s): Electrical Machines, Power System, Power Electronics, MATLAB
Credits: 02 L: 0 T: 0 P: 04 C: 2
Class schedule per week: 4 Class: M.Tech.
Semester / Level: II/05
Branch: Electrical Engineering Name of Teacher:
Class schedule per week: 3 Course Objectives:
This course enables the students to:

A.	Understand system dynamics of machines, power electronics and power system
B.	Observe speed control of DC motor, induction motors drives, BLDC motor and generator speed control for arresting the frequency of power system network
C.	Discriminate and predict the change in dynamics owing to various disturbances
D.	Design the proper controller to achieve time domain and frequency domain specifications
E.	Evaluate the performance of close loop controlled electric drive in terms of cost and efficiency.

Course Outcomes:
After the completion of this course, students will be able to:

1.	List different MATLAB blocks required for power electronics and machine simulation.
2.	Relate the concepts of power electronics in the simulation domain.
3.	Analyze simulation models in the field of power conversion and transmission
4.	Evaluate accuracy of simulation-based systems as compared to real system
5.	Design complex systems in simulation environment and lead a team of experts in power electronics and electrical drives systems for hardware design.

List of Experiments

1	**Four Quadrant Chopper based 1H.P. DC motor drive with closed loop speed control.** Objective:	
	i	Dynamic analysis of speed curve under no load and load condition.
	ii	Analysis of speed with respect to duty cycle.
2	**Class C-Chopper based 1H.P. DC motor drive open loop speed control**	
	i	Dynamic analysis of speed curve under no load and load condition.
	ii	Analysis of speed with respect to duty cycle.
3	**Single phase fully controlled rectifier based DC drive using microcontroller**	
	i	Design logic for firing scheme for rectifier.
	ii	Dynamic analysis of speed curve under no load and load condition.
	iii	Derive experimental relationship between firing angle and speed.
4	**LabVIEW based semi-controlled rectifier fed DC drive**	
	i	Design logic for firing scheme for rectifier in LabVIEW
	ii	Dynamic analysis of speed curve under no load and load condition.
	iii	Derive experimental relationship between firing angle and speed.
5	**Real time flux estimation of three phase induction motor using LabVIEW.**	
	i	Mathematical implementation of flux estimation using LabVIEW.
	ii	Estimation of torque
6	**Space Vector Modulation based Induction Motor Drive**	
	i	Getting acquainted with Space Vector Modulation
	ii	Experimental verification of Space Vector Modulation
7	**Arduino microcontroller based position control of servo motor.**	
	i	Design logic for position control of servo motor
	ii	Derive experimental relationship between duty cycle and angular position.
8	**dSPACE based constant V/F ratio based induction motor drive in closed loop.**	
	i	Design logic for gate pulse for three phase inverter in accordance with V/F speed control algorithm
	ii	Observation of speed in open loop
9	**BLDC motor Speed Control**	
	i	Mathematical modeling of BLDC Motor
	ii	Observation of Hall-Effect Transducer Waveform along with line current
10	**Mini Project: Hardware implementation**	
	i	Prototype of assigned project for testing
	ii	PCB Layout of the developed circuit topology

Text Books:

1. P.S. Bimbhra, Generalised Theory of Electric Machines, Khanna Publications, 7th Edition, Delhi, 2010
2. M.H. Rashid, Power Electronics, PHI,

Reference Books:

1. B K Bose: Modern Power Electronics and A C Drives, PHI , Delhi
2. G K Dubey, Fundamental of Electric Drives, 2nd Edition, PHI, Delhi.
3. C.M. Ong, Dynamic Simulation of Electric Machinery, PH, NJ.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT:

Assessment Tool	% Contribution during CO Assessment
Progressive Evaluation: Lab Quizz (1)	1x10 = 10
Progressive Evaluation: Daily Evaluation	30
Progressive Evaluation: Viva	20
End Semester Evaluation: Experiment Performance	30
End Semester Evaluation: Lab Quiz (1)	10

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

Mapping between course outcomes and program outcomes

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3	2	2	1	3	2	1
CO2	3	3	3	3	2	2	3	2	2
CO3	3	3	3	3	3	2	3	3	2
CO4	3	3	3	3	3	3	3	3	3
CO5	3	3	3	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements)

Hardware design of close loop control of motor drives

POs met through Gaps in the Syllabus: PO6

Topics beyond syllabus/Advanced topics/Design

Group assignments on practical use of power electronics in industry.

POs met through Topics beyond syllabus/Advanced topics/Design: PO6

Course Delivery methods	
CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Mini projects/Projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of NPTEL materials and internets
CD9	Simulation

Mapping between COs and Course Delivery (CD) methods

Course Outcome	**Course Delivery Method**
CO1	CD1,CD8,CD9
CO2	CD1,CD8,CD9
CO3	CD1,CD8,CD9
CO4	CD1,CD8,CD9
CO5	CD1,CD8,CD9

3rd Semester

Open Electives

COURSE INFORMATION SHEET
(OE I)

Course code: EE585
Course title: Hybrid Electric Vehicles
Pre-requisite(s): Electrical Machines, Power Electronics and Electrical Drives

Co- requisite(s): Induction Motor, BLDC Motor, Battery, Power Converters

Credits: 03 L:3 T:0 P:0 C: 03

Class schedule per week: 03

Class: M.TECH.
Semester / Level: XX/05
Branch: EEE

Course Objectives
This course enables the students to:

A	Understand basic working principle of power converter controlled traction drive.
B	Apply power converters in order to provide proper power modulation.
C	Analyze transient performance of power converters for meeting traction load requirement.
D	Evaluate cost of design of HEV
E	Design a suitable power converter for HEV.

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

CO1	Describe fundamental working principle of power converter controlled traction drive.
CO2	Apply power converters in conjunction with IC engine for obtaining dynamic requirement of traction drive.
CO3	Analyze mutual effect of power converter and IC engine for obtaining optimal performance of HEV.
CO4.	Evaluate cost effectiveness and optimize performance parameters.

CO5.	Design an HEV for a particular application with the help of interdisciplinary team work.

Syllabus

Module I: Introduction

Hybrid and Electric Vehicles (HEV): History Overview and Modern Applications, Ground vehicles with mechanical powertrain and reasons for HEV development, HEV configurations and ground vehicle applications, Advantages and challenges in HEV design. [8L]

Module II: Power Flow and Power Management Strategies in HEV

Mechanical power: generation, storage and transmission to the wheels, Vehicle motion and the dynamic equations for the vehicle., Vehicle power plant and transmission characteristics and vehicle performance including braking performance., Fuel economy characteristics of internal combustion engine, Basic architecture of hybrid drive train and analysis series drive train., Analysis of parallel, series parallel and complex drive trains and power flow in each case., Drive cycle implications and fuel efficiency estimations. [8L]

Module III: Hybrid Electric Vehicle

Concept of Hybrid Electric Drive Trains, Architectures of Hybrid Electric Drive Trains, Series Hybrid Electric Drive Trains, Parallel Hybrid Electric Drive Trains, Torque-Coupling Parallel Hybrid Electric Drive Trains, Speed-Coupling Parallel Hybrid Electric Drive Trains, TorqueCoupling and Speed-Coupling Parallel Hybrid Electric Drives. [8L]

Module IV: Electric Vehicles

Traction Motor Characteristics, Tractive Effort and Transmission Requirement, Vehicle Performance, Tractive Effort in Normal Driving, Energy Consumption [8L]

Module V: Design of Hybrid Electric Vehicles

Design of Series Hybrid Electric Vehicle, Design of Parallel Hybrid Electric Vehicle, Design of Electric Vehicle, Impact on Environment [8L]

Books recommended:

TEXT BOOK

1. Modern Electric, Hybrid Electric and Fuel Cell Vehicles. Mehrdad Ehsani, CRC Press
2. Modern Electric Vehicle Technology, C.C. Chan and K.T. Chau, Oxford University Press

REFERENCE BOOK

1. R.Krishnan, „Electric motor drives‟ , Prentice hall of India,2002
2. T.J.E. Miller, „Brushless magnet and Reluctance motor drives‟,

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	% Contribution during CO Assessment
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	2	2	1
CO2	3	3	3	2	2	1
CO3	3	3	3	3	2	2
CO4	3	3	3	3	3	2
CO5	3	3	3	3	2	3

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):
Design of Battery Charging Infrastructure for Hybrid Electric Vehicle

POs met through Gaps in the Syllabus: PO6

Topics beyond syllabus/Advanced topics/Design
Assignments: Regenerative Braking, Self -Driven HEV

POs met through Topics beyond syllabus/Advanced topics/Design: PO5

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Mini projects/Projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of NPTEL materials and internets
CD9	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Mapping Between COs and Course Delivery (CD) methods	
Course Outcome	**Course Delivery Method**
CO1	CD1, CD2, CD3, CD5
CO2	CD1, CD2, CD3, CD5
CO3	CD1, CD2, CD3, CD5
CO4	CD1, CD2, CD3, CD5
CO5	CD1, CD2, CD3, CD5

COURSE INFORMATION SHEET
(OE I)

Course Code: EE587
Course title: ELECTROMECHANICAL ENERGY CONVERSION
Pre-requisite(s): Basic Laws of Electromagnetism
Credits: L:03 T:0 P:0 C: 03
Class schedule per week: 03 Class: M.Tech.
Semester / Level: I/05
Branch: Electrical Engineering

Course Objectives:
This course enables the students to:

A	Explore the basic principles of transformer, dc and ac machines and analyse comprehensively their steady –state behaviours
B	Examine characteristics of static and dynamic dc and ac machines
C	Explore the technique to draw armature winding of dc machine
D	Analyse the Magnetic circuit of transformer in order to evaluate their performance,
E	Design and recommend low cost and high-performance machines which finds applications in modern industries, homes and offices.

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

CO1	State and explain working principle, constructions as well as steady- state behaviour of an ac static and dc machines.
CO2	Interpret the different transformer and dc machines
CO3	Identify, formulate and solve problems related to power transformer and dc machines.
CO4	Specify, interpret data, design an electrical machine and make a judgment about the best design in all respect.
CO5	Evaluate the design of electrical machine.

SYLLABUS

Module I:

Basic Concepts of Electromechanical Energy Conversion:
Electromagnetic induction, flux linkage, Classification and description of electrical machines, Rotor, Stator and field excitation. Generator and motor action, EMF and torque equations,

Classification and description of electrical machines, Leakage flux, Losses and efficiency, Rating, Electrical and mechanical degrees. [8L]

Module II:

Transformers: Construction**,** Principle of operation, Ideal and physical transformer, emf equation, transformation ratio, Phasor diagram. Equivalent circuit, Losses and efficiency, Autotransformer, 3-phase transformer, Three-phase transformer connections- Star-star, Delta-delta, Star-delta, Delta-star. [8L]

Module III:

Introduction to D.C. Machines: Principle of operation, Armature winding- Lap and wave, Simplex and duplex, Method of excitation, emf and torque equations, commutation.

DC Generators: Magnetization characteristics, Critical resistance and critical speed, Process of building up of voltage.

D.C. Motors: Basic equation for voltage, Power, Torque and speed, Operating characteristics- Torque-current, and Speed-current and Torque-speed characteristics. Starters, Speed control methods, Swinburnes. [8L]

Module IV:

Synchronous Machine: Principle of operation, Excitation system, Effect of winding factor on EMF, Circuit model, Phasor diagram, O.C. and S.C. tests, Short-circuit ratio, Determination of voltage regulation by synchronous impedance, MMF and zero power factor methods. Two reaction theory, Power-angle characteristic of synchronous generators, synchronizing power and torque, synchronizing methods. [8L]

Module V:

3-phase Induction Motor: Principle of operation, Slip and rotor frequency, Comparison with transformer, Equivalent circuit model, Torque and power output, Losses and efficiency, Torqueslip characteristics, Effect of rotor resistance, Starting torque and maximum torque, Starting and speed control methods.

1-phase Induction Motor: Introduction, Double revolving field theory, Crossfield theory, Torque-speed characteristic, Equivalent circuit model. [8L]

Books recommended:

TEXT BOOK

I. J. Nagrath, D.P. Kothari, Electric Machines, 4th Edition, TMH, New Delhi, 2014.
II. "P. S. Bimbhra, Electrical Machines, Khanna Publishers, New Delhi, 7th Edition 2014.

REFERENCE BOOKS:

1. A.E. Fitzgerald, Charles Kinsley, Stephen D. Umansd; Electric Machinery, McGraw Hill Education (India) Pvt. Ltd, Noida, Indian 6th Edition 2003.
2. E.H. Langsdorf; Theory of Alternating Current Machinery, McGraw-Hill, New York 1955.M.G. Say.
3. "Alternating Current Machines", Pitman Publishing Ltd. 1976.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	2	2	2	1
CO2	3	3	3	3	M	2
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	3
CO5	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):

(1) Cost Evaluation of Electrical drive in electrical machines based on reliability.
(2) Application of artificial intelligence in Electrical Machines.
(3) Study of impact of Electrical Machine on society and environment

POs met through Gaps in the Syllabus: PO6

Topics beyond syllabus/Advanced topics/Design:

(1) Reliability analysis in Electrical Machine topologies
(2) Application of adaptive algorithms in Electrical Machine based systems.

POs met through Topics beyond syllabus/Advanced topics/Design: PO6

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD6
CO2	CD1, CD6,CD7
CO3	CD1, CD2, CD3,CD6,CD7
CO4	CD1, CD3,CD6,CD7
CO5	CD1,CD2,CD3,CD4,CD5,CD7

COURSE INFORMATION SHEET

(OE I)

Course Code: EE589
Course title: POWER SEMICONDUCTOR DEVICES
Pre-requisite(s): Basic Electronics
Credits: 03 L:3 T:0 P:0 C: 03

Class schedule per week: 03
Class: M.Tech.
Semester / Level: I/05
Branch: Electrical Engineering

Course Objectives:
This course enables the students to:

A.	Identify different type of modern semiconductor-based switching devices and their operating characteristics.
B	Explain working principle of semiconductor devices such as Thyristors and PMOSFET.
C.	Analyze protection circuit and firing circuit.
D.	Evaluate performance parameters of a semiconductor device
E.	Design protection for power semiconductor devices.

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

CO1.	List different types of semiconductor devices and remember their operating characteristics. Explain the working principle of different semiconductor devices.
CO2.	Classify different types of power converters. Show suitability of a power converter for a particular application. Solve power management related problems with application of power electronics based topologies.
CO3.	Outline shortcomings of each class of power devices and solve them using proper circuits such as firing circuit and protection circuit.

CO4.	Estimate the cost and long-term impact of power electronics technology on a large-scale project of socio-economic importance.
CO5	Design protection circuit such as thermal protection, dv/dt protection and di/dt protection.

SYLLABUS

Module I:

Introduction: Power switching devices overview – Attributes of an ideal switch, application requirements, circuit symbols; Power handling capability – (SOA); Device selection strategy– On-state and switching losses – EMI due to switching – Power diodes – Types, forward and

reverse characteristics, switching characteristics – rating. [8L]

Module II:

Current Controlled Devices: BJT‟s – Construction, static characteristics, switching characteristics; Negative temperature coefficient and second breakdown; – Thyristors – Physical and electrical principle underlying operating mode, Two transistor analogy – concept of latching; Gate and switching characteristics; converter grade and inverter grade and other types; series and parallel operation; comparison of BJT and Thyristor – steady state and dynamic models of BJT &Thyristor- Basics of GTO, MCT, FCT, RCT. [8L]

Module III:

Voltage Controlled Devices: Power MOSFETs and IGBTs – Principle of voltage-controlled devices, construction, types, static and switching characteristics, steady state and dynamic models of MOSFET and IGBTs – and IGCT. New semiconductor materials for devices – Intelligent power modules- Integrated gate commutated thyristor (IGCT) – Comparison of all power devices.

[8L]

Module IV:

Firing and Protection Circuits: Necessity of isolation, pulse transformer, optocoupler – Gate drives circuit: SCR, MOSFET, IGBTs and base driving for power BJT. – Over voltage, over current and gate protections; Design of snubbers. [8L]

Module V:

Thermal Protection: Heat transfer – conduction, convection and radiation; Cooling – liquid cooling, vapour – phase cooling; Guidance for hear sink selection – Thermal resistance and impedance -Electrical analogy of thermal components, heat sink types and design – Mounting types- switching loss calculation for power device. [8L]

Books recommended: Text Books:

1. M.H. Rashid,"Power Electronics: Circuits, Device and Applications",2nd Ed.n, PHI, New Jersey, 1993.
2. Mohan, Underland, Robbins; Power Electronics Converters, Applications and Design, 3rd Edn., 2003, John Wiley & Sons Pte. Ltd.
3. M. D. Singh, K. B. Khanchandani, "Power Electronics", 2nd Edn., Tata McGraw- Hill, 2007. **Reference Books:**

1. R. Krishnan, "Electric Motor Drives: Modeling, Analysis and Control", 1st Edn., Prentice Hall,2001.
2. B. K. Bose, "Modern Power Electronics & AC Drives" , 1st Edn., Prentice Hall, 2001
3. L. Umanand, "Power Electronics: Essentials & Applications", 1st Edn. Wiley India Private Limited, 2009.
4. Jeremy Rifkin, "Third Industrial Revolution: How Lateral Power Is Transforming Energy, the Economy, and the World", 1st Edn., St. Martin"s, Press, 2011.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	2	2	2	1
CO2	3	3	2	2	1	1
CO3	3	3	3	2	1	1
CO4	3	3	3	3	2	1
CO5	3	3	3	3	3	2

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements) :

(1) Cost Evaluation of Power Electronics based installation based on reliability

(2) Study of impact of power electronics on society and environment

POs met through Gaps in the Syllabus: PO6

Topics beyond syllabus/Advanced topics/Design:

(1) Reliability analysis in power electronics topologies

(2) Application of power electronics in the field of Renewable Energy.

POs met through Topics beyond syllabus/Advanced topics/Design: PO6

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD6
CO2	CD1, CD6,CD7
CO3	CD1, CD2, CD3,CD6,CD7
CO4	CD1, CD3,CD6,CD7
CO5	CD1,CD2,CD3,CD4,CD5,CD7

COURSE INFORMATION SHEET
(OE II)

Course code: EE595
Course title: SMART GRID
Pre-requisite(s): Power system courses, Power Electronics
Co- requisite(s):
Credits: 03 L: 03 T: 0 P: 0 C: 03
Class schedule per week: 3
Class: M. Tech
Semester / Level: I/05
Branch: EEE

Course Objectives: The course objectives are

A.	Introduction to grid operation, necessity of making grid more smart, and basic components of today's grid.
B.	Extend knowledge on different design challenges with grid interfacing systems for Renewable Energy Sources.
C.	Illustrate the basics of the working principle of PMU and its application.
D.	Educate the students about communication protocol and its application in smart grid.
E.	To make the students understand different demand response programmes.

Course Outcomes: After the completion of this course, students will be able to

1.	Demonstrate steps about building blocks of the smart grid.
2.	Organise the steps involved in working principles of PMU and WAMS through PMUs
3.	Analysis the challenges involved with grid interactive converters connected with RES.

4.	Understand the design concept involved with demand response Programmes, communication standards, cyber security etc.
5	Aspire and confident for taking up challenge to adopt new technology needed for monitoring, control and operation of power system.

Syllabus

Module-1: Introduction [8L]

Basics about Power Grid operation, Concept of Smart Grid, necessity for pushing smart grid concept, operation and control architecture, Basic components

Module 2: Smart Grid and Generation [8L]

Renewable energy generation, Solar, Wind, Hydroelectric, Biomass, fuel cell, challenges with RE generation, uncertainty and risk estimation, concept of Converter design for grid tied RE sources.

Module 3: Smart Grid and transmission system [8L]

Introduction, Wide area monitoring system, Phasor measurement units (PMUs) smart meters, multi-agent system technology, phasor measurement techniques: introduction, phasor estimation of nominal frequency signals, phasor updation using non-recursive and recursive updates, phasor estimation at off-nominal frequency input, hierarchy of phasor measurement systems, communication options for PMUs, functional requirements of PMUs and phasor data concentrators (PDCs).

Module 4: Smart Grid and Communication system [8L]

Introduction, communication requirement, list of the standards, architecture of the communication system, wired and wireless communication, security and safety.

Module 5: **Smart Grid and Demand Response**: Introduction, demand response, Types of demand Response Programmes, Aggregator concept, Advanced metering infrastructure, Smart home and building automation standards. Basic concept of Big data analysis. [8L]

Test Book:

1. Smart Grid Standards : Specifications, Requirements, and Technologies by by Takuro Sato, Daniel M. Kammen, , Bin Duan, , Martin Macuha, Zhenyu Zhou, , Jun Wu, Muhammad Tariq, , and Solomon A. Asfaw PUBLISHER John Wiley & Sons, Incorporated
2. A.G. Phadke J.S. Thorp, “Synchronized Phasor Measurements and their Applications”, springer 2008
3. James Momoh, **“**SMART GRID: Fundamentals of Design and Analysis”, IEEE (Power engineering series) – Wiley- Blackwell, April 2012

4. Janaka Ekanayake, Kithsiri Liyanage, JianzhongWu, Akihiko Yokoyama, Nick Jenkins "Smart Grid Technology and Applications", Wiley, New- Delhi, August 2015

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

Mapping between CO and PO

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	1	3	3	2	2
CO2	3	3	3	2	1	2
CO3	2	3	2	3	2	3
CO4	3	2	3	3	3	3
CO5	3	2	3	2	2	1

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements):
Design of real-time industrial projects.

POs met through Gaps in the Syllabus: **PO5 & PO6**

Topics beyond syllabus/Advanced topics/Design:
Design optimization for industrial projects, Fractional order controller

POs met through Topics beyond syllabus/Advanced topics/Design: PO5 & PO6 Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	**Course Delivery Method**
CO1	CD1,CD6
CO2	CD1, CD6,CD7
CO3	CD1, CD2, CD3,CD6,CD7
CO4	CD1, CD3,CD6,CD7
CO5	CD1,CD2,CD3,CD4,CD5,CD7

COURSE INFORMATION SHEET
(OE II)

Course Code: EE 597
Course title: Reliability Engineering
Pre-requisite(s): Knowledge of basic power system and control system courses.
Co- requisite(s): B.E./B.Tech. in ECE/EEE with basic courses on Power System

Credits: 03 L: 3 T: 0 P: 0 C: 03
Class schedule per week: 3
Classes per week
Class: M.Tech.
Semester / Level: I/05
Branch: Electrical Engineering

Course objectives:
This course enables the students to:

1.	Define probability theory and relate the concept of reliability of systems
2.	Understand general reliability mathematics applicable to all systems.
3.	Understand Markov chains, and application of Markov models in reliability analysis of systems.
4.	Evaluate reliability of systems using Markov models and available reliability parameters of systems.
5.	Use frequency and duration technique for various reliability analysis problems.

Course outcomes:

1.	Understand the general reliability concept and mathematics
2.	Identify events or causes responsible for unreliability of systems through failures.
3.	Evaluate the associated system risk and thus finding solutions for minimizing the risks to an acceptable level.
4.	Apply engineering knowledge and design techniques to prevent or to reduce the likelihood or frequency of failures for different systems.

5.	Apply methods for estimating the reliability of new designs, and for analyzing reliability data.

Syllabus

Module 1

Introduction: Types of systems, Qualitative and quantitative assessment ,Reliability definitions and concepts, Reliability indices and criteria, Reliability evaluation techniques, Reliability improvements, Reliability economics, Reliability monitoring and growth, Basic probability theory**,** Probability concepts, Permutations and combinations, Application in probability evaluation, Practical engineering concepts, Venn diagrams, Rules for combining probabilities, Probability distributions. [8L]

Module 2

Reliability Mathematics : The general reliability function, The exponential distribution, Mean time to failure and repair, series and parallel systems, Markov processes, System reliability using network and state space method [8L]

Module 3

Network modelling and evaluation of simple and complex systems: Service quality criterion, Conditional probability approach, Two-plant single load and two load systems. The probability array for two interconnected systems, Loss of load approach, Interconnection benefits. [8L]

Module 4

Discrete Markov chains and Continuous Markov processes: Introduction to Discrete Markov chain, Stochastic transitional probability matrix by Discrete Markov chain, Time dependent probability evaluation by Discrete Markov chain**,** Limiting state probability evaluation**,** Absorbing states, Application of discrete Markov techniques, Introduction to Continuous Markov process**,** General modeling concepts, State space diagrams, Stochastic transitional probability matrix by Continuous Markov process , Evaluating limiting state probabilities by Continuous Markov process, Reliability evaluation in repairable systems, Application of techniques to complex systems. [8L]

Module 5

Frequency and duration techniques: Frequency and duration concepts, Application to multistate problems: Two component repairable system, State probabilities, Frequency of encountering individual states**,** Mean duration of individual states, Cycle time between individual states , Frequency of encountering cumulated states**,** Recursive evaluation of cumulative frequency**,** Mean duration of cumulated states, Frequency balance approach, Two stage repair and installation process :One component system-no spare available**,** one spare available**,** two spares available**,** one spare available**,** Limiting number of spares, Application of the techniques. [8L]

Text Books:

1. Roy Billinton, Ronald N. Allan, "Reliability Evaluation of Engineering Systems Concepts and Techniques", 2nd Edition, Springer Science + Business Media New York 1992.
2. Hoang Pham, "Handbook of Reliability Engineering", Springer 2003.
3. Alessandro Birolini, "Reliability Engineering: Theory and Practice", Springer 1999.

Reference Books:

1. Donald W. Benbow, "The Certified Reliability Engineer Handbook", 2009.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

<u>MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES</u>

CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	2	3		1
CO2	3	3	2	2	1	1
CO3	3	3	2	2	1	1
CO4	3	3	2	2	1	1
CO5	3	3	2	2	1	1

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements): Case studies of real network

POs met through Gaps in the Syllabus: PO6

Topics beyond syllabus/Advanced topics/Design: Case study presented in IEEE Journal Papers

POs met through Topics beyond syllabus/Advanced topics/Design: PO 6

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1, CD6
CO2	CD1, CD6, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD5, CD7

COURSE INFORMATION SHEET
(OE II)

Course code: EE601
Course title: Process Measurement and Control.
Pre-requisite(s):
Co- requisite(s):
Credits: L:3 T:0 P:0
Class schedule per week: 03
Class: MTech
Semester / Level: III
Branch: control/ EEE
Name of Teacher:

Course Objectives

This course enables the students to:

A.	Comprehend the advanced control methods used in industries and research.
B	Demonstrate design approach to a class of real and practically significant industrial problems.
C	Analyze design applications in a clear, concise manner
D	Organize basic principles and problems involved in process control and to give look at an overall problem
E	Revise the responses of basic systems that often are the building blocks of a control system.

Course Outcomes

After the completion of this course, students will be able to:

CO1.	Identify the different type of controller that can be used for specific problems in process industry
CO2.	Model several physical systems that can be represented by a first-order and 2nd order transfer function.
CO3.	Analyze the actual physical mechanisms,
CO4.	Design and tuning of controllers for interacting multivariable systems
CO5	Validate and design of digital control systems

SYLLABUS

Module-I:

The general control system, transfer functions, process characteristics. Concept of feedback and feed forward control system, process measurements- temperature, pressure, flow, level, physical properties - density, viscosity, pH, power, rotational speed. [8L]

Module-II:

Final control element, control valves and their characteristics, the controller, proportional integral, proportional integral derivatives controller, pneumatic and hydraulic controller. Servomotor technology in control. [8L]

Module-III:

Control system dynamics: transfer function of first order, second order systems. Response of control loop components to forcing functions. Transfer function of feedback control system. Tests for unstable system. [8L]

Module-IV:

Advanced control systems: multivariable control problem, ratio control, cascade control, computed variable control, feed forward control, override control, adaptive control. [8L]

Module-V:

Application of computer control, online computer control, servomotor technology in control, brief idea about application of dynamic matrix control, predictive control, Fuzzy logic control [8L]

Books Recommended:

1. "Process Control", F. G. Shinskey, McGraw Hill Book Company.
2. "Process, Modeling, Simulation and Control for Chemical Engineers", W. L. Luyben, McGraw Hill.
3. D.R. Coughanour, „Process Systems analysis and Control‟, McGraw-Hill, 2nd Edition, 1991.
4. Coughanouer and Koppel, Process System analysis and Control

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

DIRECT ASSESSMENT

Assessment Tool	**% Contribution during CO Assessment**
Quizzes (3)	3x10 = 30
Seminar	10
Teacher's Assessment	10
Semester End Examination	50

INDIRECT ASSESSMENT –

1. Students' Feedback on Course Outcome

Mapping Between Objectives and Outcomes Mapping of Course Outcomes onto Program Outcomes

Course Outcome	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	-	-	-
CO2	2	3	1	2	2	2
CO3	3	2	1	2	2	2
CO4	2	2	2	2	2	2
CO5	2	2	2	2	2	2

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Gaps in the syllabus (to meet Industry/Profession requirements)

Concepts of processing plant

POs met through Gaps in the Syllabus: PO5&PO6

Topics beyond syllabus/Advanced topics/Design

POs met through Topics beyond syllabus/Advanced topics/Design

Course Delivery methods	
CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Mini projects/Projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of NPTEL materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD8,CD9
CO3	CD1,CD2,CD3,CD8
CO4	CD1,CD2,CD3
CO5	CD1,CD2,CD3