AY 2019-20 ONWARDS

Course Structure and Curriculum

Master of Technology in Electrical Engineering

(Specialization: Power Electronics Control and Drives)

DEPARTMENT OF ELECTRICAL ENGINEERING

VEER SURENDRA SAI UNIVERSITY OF TECHNOLOGY, ODISHA,

BURLA – 768018

VISION

To be recognized as a centre of excellence in education and research in the field of Electrical Engineering by producing innovative, creative and ethical Electrical Engineering professionals for socio-economic development of society in order to meet the global challenges.

MISSION

Electrical Engineering Department of VSSUT Burla strives to impart quality education to the students with enhancement of their skills to make them globally competitive through:

M1.   Maintaining state of the art research facilities to provide enabling environment to create, analyze, apply and disseminate knowledge.

M2.   Fortifying collaboration with world class R&D organizations, educational institutions, industry and alumni for excellence in teaching, research and consultancy practices to fulfil 'Make in India' policy of the Government.

M3.   Providing the students with academic environment of excellence, leadership, ethical guidelines and lifelong learning needed for a long productive career.

PROGRAM EDUCATIONAL OBJECTIVES

The program educational objectives of M.Tech.in Electrical Engineering (Power Electronics Control and Drives) program of VSSUT Burla are to prepare its graduates:

1.   To acquire competency in analysis, design, modeling, programming and optimization skills to meet industrial challenges for solving real life problems and undertake research in broad area of power electronics, control systems and electric drives.

2.   To excel in their professional career/entrepreneurial skill/research and higher studies and lead in the conception, design and implementation of new products, processes, services and systems according to the prevailing socio-economic context.

3.   To augment the specialized workforce in the domain of power electronics, control systems and electric drives in private, government and public sector industries, educational institutions and state-of-the-art research laboratories.

PEO-MISSION MATRIX

	M1	M2	M3
PEO1	3	1	1
PEO2	1	3	2
PEO3	2	3	3

PROGRAM OUTCOMES of M.Tech. (PECD)

PO1	An ability to independently carry out research/investigation and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report/document
PO3	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.
PO4	An ability to create, select, learn and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex problems in power electronics, control systems and electric drives with an understanding of the limitations.
PO5	An ability to understand of group dynamics, recognize opportunities and contribute positively to collaborative-multidisciplinary scientific research involving power electronics, control systems and electric drives in order to achieve common goals.
PO6	Demonstrate a capacity for self-management and teamwork, decision-making based on open-mindedness, objectivity and rational analysis to further the learning of themselves as well as others.

Program Specific Outcomes for M.Tech. (PECD)

PSO1	Ability of design, modelling and analysis of power electronics, control systems and electric drives components using the latest available tools.
PSO2	Develop suitable techniques and cutting-edge power electronics based hardware and software for the solution of practical problems.

COURSE STRUCTURE

Semester I

Sl. No.	Core/ Elective	Subject Code	Subject Name	L	T	P	Credits
1	Core-1	MEEPD101	**Power Electronic Converters-I**	3	0	0	3
2	Core-2	MEEPD102	**Dynamics of Electrical Machines**	3	0	0	3
3	PE-1		**PE-1**	3	0	0	3
4	PE-2		**PE-2**	3	0	0	3
5	Common		**Research Methodology & IPR**	3	0	0	3
6	Lab-1	MEEPD103	**Power Electronics and Drives Lab-I**	0	0	6	4
8	Audit -1		**Audit -1**				
Total Credits							19

Semester II

Sl. No.	Core/ Elective	Subject Code	Subject Name	L	T	P	Credits
1	Core-3	MEEPD201	**Power Electronic Converters-II**	3	0	0	3
2	Core-4	MEEPD202	**Advanced Machine Drives**	3	0	0	3
3	PE-3		**PE-3**	3	0	0	3
4	PE-4		**PE-4**	3	0	0	3
5	Common		**Minor project & Seminar**	0	0	4	2
6	Lab-2	MEEPD203	**Power Electronics and Drives Lab-II**	0	0	6	4
8	Audit -2		**Audit -2**				
Total Credits							18

Semester III

Sl. No.	Core/ Elective	Subject Code	Subject Name	L	T	P	Credits
1	PE-5		**PE-5**	3	0	0	3
2	OE-1		**OE-1**	3	0	0	3
3	Project		**Dissertation (Phase-I)**	0	0	20	10
Total Credits							16

Semester IV

Sl. No.	Core/ Elective	Subject Code	Subject Name	L	T	P	Credits
1	Project		**Dissertation (Phase-II)**	0	0	32	16
Total Credits							16

GRAND TOTAL CREDITS: 19+18+16+16= 69

Program Electives

First Semester			
Program Elective-I		**Program Elective-II**	
MPDPE101	Electric Drive Systems	MPDPE104	Advanced Control Systems
MPDPE102	Power Quality	MPDPE105	Static VAR Controllers and Harmonic Filtering
MPDPE103	Grid Integration of Renewable Power	MPDPE106	Electric and Hybrid Vehicles
Second Semester			
Program Elective-III		**Program Elective-IV**	
MPDPE201	Advanced Digital Signal Processing	MPDPE204	Embedded Systems
MPDPE202	Industrial Load Modeling and Control	MPDPE205	Industrial Automation and Control
MPDPE203	Special Electrical Machines	MPDPE206	FACTS and Custom Power Devices
Third Semester			
Program Elective-V		**Open Electives**	
MPDPE301	Smart Power Grids	MPDOE301	Non-linear system theory
MPDPE302	Machine Learning and AI	MPDOE302	Operations Research
MPDPE303	Nonlinear Dynamics	MPDOE303	Industrial Safety
MPDPE304	SCADA System and Applications	MPDOE304	Waste to Energy

Audit course 1 & 2

Sl.No.	Course Code	Subject Name
1.	BCAC1001	English for Research Paper Writing
2.	BCAC1002	Disaster Management
3.	BCAC1003	Sanskrit for Technical Knowledge
4.	BCAC1004	Value Education
5.	BCAC2001	Constitution of India
6.	BCAC2002	Pedagogy Studies
7.	BCAC2003	Stress Management by Yoga
8.	BCAC2004	Personality Development through Life Enlightenment Skills.

First Semester

Program Core Courses

Power Electronics Converters-I

MODULE-I (8 HOURS)
Line Frequency Diode Rectifiers.Single-Phase Diode Bridge Rectifiers with Capacitor Filter.VoltageDoubleRectifiers.Effect of Single Phase Rectifiers on Neutral Currents in a Three Phase Four-Wire System. Three Phase half wave rectifier with resistive load. Three phase full wave rectifier. Double Y type rectifier.Three Phase Rectifier Circuits.Design of Power Transformers for Rectifiers.Inrush Currents and Overvoltage's at turn on in Rectifier Circuits Input Line Current Harmonics and power factor.

MODULE-II (8 HOURS)
Line Frequency Phase-Controlled Rectifiers and Inverters. Single Phase - Half Wave Controlled Rectifier with R, RL, RL with Flywheel diode loads. Full Wave Controlled Rectifier with various kinds of loads. Half Controlled and Full Controlled Bridges with passive and active loads - Input Line Current Harmonics and Power Factor- Inverter Mode of Operation.ThreePhase.Half Wave Controlled rectifier with RL Load. Half Controlled Bridge with RL Load. Fully Controlled Bridge with RL Load.Input Side Current Harmonics and Power Factor - Dual Converters.Circulating Current Mode and Non-Circulating Current Mode.

MODULE-III (8 HOURS)
AC Voltage Regulators and DC choppers-Types of ac voltage regulators -Single phase full wave ac voltage controller - Single phase transformer tap changer - Multistep transformer tap changer. D.C chopper circuits, Type-A, B, C, D and E configurations, Analysis of Type-A chopper with R-L load. -Voltage and current commutated Choppers

MODULE-IV (8 HOURS)
Switch-Mode dc-ac Inverters.BasicConcepts.Single Phase Inverters.PushPull, Half Bridge and Full Bridge Square Inverters .Blanking Time .Single Pulse Modulation of Single Phase Square Wave Inverters.Multi pulse modulation. - PWM Principles,Sinusoidal Pulse Width Modulation in Single Phase Inverters. Choice of carrier frequency in SPWM .spectral Content of output.Bipolar and Unipolar Switching in SPWM - Maximum Attainable DC Voltage Switch Utilization .Reverse Recovery Problem and Carrier Frequency Selection.Three Phase Inverters -Three Phase Square Wave /Stepped Wave Inverters.Three Phase SPWM Inverters.Choice of Carrier Frequency in Three Phase SPWM Inverters

MODULE-V (7 HOURS)

Single Phase diode rectifiers with LC filter. Cascaded LC Filter.LC Filter Design. Single phase inverter- Output Side Filter Requirements and Filter Design - Ripple in the Inverter Output - DC Side Current. Single Phase Inverters- Output Side Filter Requirements and Filter Design - Ripple in the Inverter Output - DC Side Current. Three phase inverter- Output Filters. DC Side Current.Effect of Blanking Time on Inverter Output Voltage.

BOOKS

1. Ned Mohan et.al:*"Power Electronics",* John Wiley and Sons.P.C. Sen :*"Power Electronics",* Tata McGraw Hill

2. G.K.Dubeyet.al ,*"Thyristorised Power Controllers",* Wiley Eastern Ltd.

3. B. K Bose :*"Modern Power Electronics and AC Drives",* Pearson Education (Asia)

Course Outcome:

Upon completion of the course, students will be able to:

CO1	Analyze the basic principles of switch mode power converters
CO2	Analyze the operating principles and models of different types of power electronic converters AC-AC, AC-DC, DC-AC and DC-DC converter systems.
CO3	Analyze and design switch mode power electronic converters for various applications
CO4	Apply microprocessor power supplies, renewable energy systems, and motor drives.
CO5	Analyze pulse width modulated inverters used for variable speed drives.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Dynamics of Electrical Machines

MODULE-I (9 HOURS)

Singly excited circuits, Coupled circuits, Solution of Electro-dynamical Equations by Euler's method and Runge-Kuttamethod.Linearization of the Dynamic Equations and Small Signal Stability.

Elementary DC Machine, Voltage and torque equations, Basic types of DC machines, Dynamic characteristics of DC motors, time-domain block diagrams and state equations, solution of dynamic characteristics by Laplace transformation.

MODULE-II (9 HOURS)

The basis of General Theory and Generalized Equation of A.C machines, Equation in terms of phases variable park's transformation, Various reference frames, Derivation of two-axis equation, Torque equation, Field and damper windings, Equivalent circuits, Operational impedances and frequency response loci, Modified equation with more accurate coupling between field and damper windings.

MODULE-III (9 HOURS)

Synchronous Generator short circuit and system faults: Symmetrical short circuit of unloaded generator, Analysis of short circuit oscillograms, short circuit of loaded synchronous generator, Unsymmetrical short of synchronous generator, system fault calculation, sudden load changes, Equivalent circuit under transient condition, Constant flux linkage theorem, Simplified phasor diagram for transient changes.

MODULE-IV (7 HOURS)

Induction machines: General equation of the induction motor (equation), Application of equation in primary and secondary reference frames and complex form of equation, Short circuit and fault current due to the induction motor, fault calculation.

MODULE-V (5 HOURS)

Transformers: Transient phenomena in transformer, General characteristics of over voltage and current inrush, Transient over voltage characteristics.

BOOKS

[1]. B.Adkins and R.H. Hiiley, *The Generalized Theory of Electrical Machines*, Chapman and Hall,. London, UK

[2]. P.C. Kraus, O. Wasynczuk, S.D. Sudhof, *Analysis of Electrical Machinery and Drives Systems*, IEEE Press, John Wiely and Sons, Piscataway, New Jersey, USA

[3]. P. Kundur, *Power System Stability and Control*, McGraw-Hill, 1994

COURSE OUTCOMES:

Upon completion of the subject the students will demonstrate the ability to:

CO1	Express Kron's Primitive machine as an unified electrical machine model and derive the mathematical model of DC machine for transient analysis
CO2	Develop the mathematical model of Synchronous machine for transient analysis.
CO3	Analyze a three phase synchronous machine under fault conditions.
CO4	Evaluate the mathematical model and transient analysis of 3- phase Induction motor.
CO5	Develop the mathematical model of Transformer for transient analysis.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Program Elective-I

Electric Drive Systems

MODULE-I (10 HOURS)
Introduction to Motor Drives - Components of Power Electronic Drives - Criteria for selection of Drive components - Match between the motor and the load - Thermal consideration - Match between the motor and the Power Electronics converter - Characteristics of mechanical systems - stability criteria

MODULE-II (10 HOURS)
D.C Motor Drives - System model, motor rating - Motor-mechanism dynamics - Drive transfer function - Effect of armature current waveform - Torque pulsations - Adjustable speed dc drives - Chopper fed and 1-phase converter fed drives - Effect of field weakening.

MODULE III
Induction Motor Drives - Basic Principle of operation of 3 phase motor - Equivalent circuit - MMF space harmonics due to fundamental current - Fundamental spatial mmf distributions due to time harmonics - Simultaneous effect of time and space harmonics - Speed control by varying stator frequency and voltage. Impact of non-sinusoidal excitation on induction motors.

MODULE IV
Variable frequency PWM-VSI drives - Variable frequency square wave VSI drives - Variable frequency CSI drives - Comparison of variable frequency drives - Line frequency variable voltage drives - Soft start of induction motors - Speed control by static slip power recovery. - Vector control of 3 phase squirrel cage motors - Principle of vector control.

MODULE V
Synchronous Motor Drives - Introduction - Basic principles of synchronous motor operation methods of control - operation with field weakening - load commutated inverter drives.

BOOKS
[1]Ned Mohan, "*Power Electronics*", et. al Wiley.

[2]G.K.Dubey&C.R.Kasaravada, "*Power Electronics & Drives*", Tata McGraw Hill.

[3]M.H.Rashid Power Electronics", (P.H.I.Edition)

[4]W.Shephered, L N HulleyCambride, "*Power Electronics & Control of Motor*", University Press.

[5]S.K.Pillai, Jhon Willy & Sons," A first Course on Electrical Drives"

[6] Werner Leonhard, Control of Electrical Drives, 3rd edition, Springer 2001.

Course Outcomes

Upon completion of the course, the students will demonstrate the ability to:

CO1	Analyze performance of various power electronic drives components, matching of motor, load, power electronic component, thermal consideration and mechanical system stability.
CO2	Define operation of D.C motor drive system operated by power electronics converter, motor dynamics, drive transfer function, torque behavior, adjustable speed D.C drive
CO3	Analyze the operation, equivalent circuit, time and space harmonics, speed control of three phase induction motor.
CO4	Analyze the Variable frequency PWM-VSI & variable frequency CSI drives and vector control of 3 phase squirrel cage motors
CO5	Analyze synchronous motor drives,its application and control.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Power Quality

MODULE-I (8 HOURS)

PQ Definitions and Standards General Classification of PQ Phenomena IEEE and IEC PQ Standards, PQ Monitoring and Measuring Available monitoring techniques and their drawbacks Commercial power quality monitors, Power quality monitors sensitivity PQ Problems Identification, PQ Phenomena Classification Identification and localization of PQ problems Different PQ classification techniques and case studies

MODULE-II (8HOURS)

Harmonic Sources, Effects, Analysis, and Modeling, Harmonic Distortion Mitigation Voltage vs. Current Distortion, Harmonics vs. Transients Harmonic Sources from Commercial and Industrial Loads, Time domain versus frequency domain Different Harmonic filters (passive, active and hybrid); and case studies

MODULE-III (8 HOURS)

Voltage Sag, Swell and Interruptions, Transient Over-voltages, Sources of Sags and Interruptions, Fundamental Principles of Protection, Motor-Starting Sags, Utility System Fault-Clearing. Issues, and Case Studies, Sources of Transient Overvoltage; Principles of Overvoltage Protection and Switching Transient Problems with Loads

MODULE-IV (8HOURS)

Voltage Flicker, Voltage Unbalance, Voltage Regulation Sources of voltage flicker; Effects and mitigation techniques Sources of voltage unbalance; Effects and mitigation techniques Devices for Voltage Regulation; Utility Voltage Regulator Application and End-User Capacitor Application

MODULE-V (7HOURS)

SVC and STATCOM, Active Harmonic Filtering, power quality problems created by drives, Power factor improvement, Passive Compensation, Single Phase APFC, Three Phase APFC and control technique.

BOOKS
[1]. R. Dugan, M. McGranaghan, S. Santoso and H. Beaty, Electrical Power System Quality, Second Edition, McGraw-Hill, 2002, ISBN 0-07-138622-X.

[2]. J. Arrillaga, B. Smith, N. Watson and A. Wood, Power System Harmonic Analysis, John Wiley, 1997, ISBN 0-471-97548-6.

[3]. Understanding Power Quality Problems by Math H. Bollen

[4]. J. Arrillaga, .Power System Quality Assessment., John wiley, 2000

[5]. R. SastryVedam, M. S. Sarma,"Power Quality: VAR Compensation in Power System" CRC Press, Taylor and Francis group, 2008

Course Outcomes:

Upon completion of the course, students will be able to:

CO1	Analyze the reasons for increased concern for power quality issues in power systems.
CO2	Develop the benchmarking process in power quality sector.
CO3	Incorporate the issues in power quality improvement
CO4	Apply technology in solving the problems of power quality including distribution generation.
CO5	Analyze the various monitoring methods used in power quality issues and control the power quality issues.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Grid Integration of Renewable Power

Module-1(8 hours)

Power system operation: Introduction on electric grid, Supply guarantees, power quality and Stability, Introduction to renewable energy grid integration, concept of mini/micro grids and smart grids; Brief over view of Wind, Solar, Biomass power generation scheduling techniques.

Module-2 (8 hours)

Control of frequency and voltage of distributed generation in Stand-alone and Grid-connected mode, use of energy storage and power electronics interfaces for the connection to grid and loads.Design and optimization of size of renewable sources and storages. Power quality problems and fault-ride through capability of microgrid.

Module-3 (8 hours)

Introduction to basic analysis and operation techniques on power electronic systems; Functional analysis of power converters, Power systems control using power converters; Electronic conversion systems application to renewable energy generation systems.

Module-4 (8 hours)

Power control and management systems for grid integration, island detection systems, synchronizing with the grid; Issues in integration of converter based sources; Netwok voltage management; Power quality management and Frequency management; Influence of PV/WECS on system transient response.

Module-5 (7 hours)

Simulation tools, Simulation of grid connected/off grid renewable energy system (PV/WEC S); Design of Gird-interactive photovoltaic systems for house hold applications.

Books

[1] Bollen M. H. and Hassan F. (2011); Integration of Distributed Generation in the Power System, Wiley- IEEE Press

[2] Vittal V. and Ayyanar R. (2012); Grid Integration and Dynamic Impact of Wind Energy, Springer Reference Books

[3] Keyhani A. (2011); Design of Smart Power Grid Renewable Energy Systems, Wiley–IEEE Press

[4] Teodorescu R. Liserre M. Rodriguez P. (2011); Grid Converters for Photovoltaic and Wind Power Systems, First Edition, Wiley- IEEE Press

[5] S. Heier and R. Waddington *'Grid Intergration of Wind Energy Conversion Systems'*, Wiley, 2006.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Define electric grid, power quality, Stability, renewable energy grid integration.
CO2	Analyze control of frequency and voltage of distributed generation in Stand-alone and Grid-connected mode.
CO3	Demonstrate operation techniques on power electronic systems, power systems control using power converters, electronic conversion systems.
CO4	Analyze power control and management systems for grid integration, island, power quality management.
CO5	Analyze simulation tools, simulation of grid connected/off grid renewable energy system.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Program Elective-II

Static VAR Controllers & Harmonic Filtering

Module 1:

Fundamentals of Load Compensation.Steady-State Reactive Power Control in Electric Transmission Systems. Reactive Power Compensation and Dynamic Performance of Transmission Systems

Power Quality Issues: Sags, Swells, Unbalance, Flicker, distortion, Current Harmonics. Sources of Harmonics in Distribution Systems and effects.

Module 2:

Static Reactive Power Compensators and their control. Shunt Compensators. SVCs of Thyristor Switched and Thyristor Controlled types and their control, STATCOMs and their control.Series Compensators of thyristor Switched and Controlled Type and their Control.SSSC and its Control, Sub Synchronous Resonance and damping.Use of STATCOMs and SSSCs for Transient and Dynamic Stability Improvement in Power System.

Module 3:

Converters for Static Compensation. Single Phase and Three Phase Converters and Standard Modulation Strategies (Programmed Harmonic Elimination and SPWM). GTO Inverters.Multi-Pulse Converters and Interface Magnetics. Multi-Level Inverters of Diode Clamped Type and Flying Capacitor Type

Module 4:

Passive Harmonic Filtering.Single Phase Shunt Current Injection Type Filter and its Control. Three Phase Three-wire Shunt Active Filtering and their control using p-q theory and d-q modeling. Three phase four wire shunt active filters.Hybrid Filtering using Shunt Active Filters.Dynamic Voltage Restorer and its control. Power Quality Conditioner

Module 5:

Series Active Filtering in Harmonic Cancellation Mode. Series Active Filtering in Harmonic Isolation Mode

Books:

1. Ned Mohan et.al, "Power Electronics", John Wiley and Sons, 2006.
2. G. Massobrio, P. Antognet," Semiconductor Device Modeling with Spice", McGrawHill, Inc., 1988.
3. B. J. Baliga," Power Semiconductor Devices", Thomson, 2004
4. V. Benda, J. Gowar, D. A. Grant," Power Semiconductor Devices.Theory and Applications", John Wiley& Sons 1994.

Course Outcomes:

CO1	Express about Steady-State Reactive Power Control Systems, Reactive Power Compensation and Dynamic Performance of Transmission Systems and power quality issues;
CO2	Evaluate the fundamental principles of Passive and Active Reactive Power Compensation Schemes at Transmission and Distribution level in Power Systems
CO3	Express various single phase and three-phase Static VAR Compensation schemes and their controls;
CO4	Analyze Passive Harmonic Filtering
CO5	Analyze Series Active Filtering in Harmonic Cancellation.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Advanced Control Systems

MODULE-I

Linearization of nonlinear systems, SISO Control Analysis and Design Analysis of SISO Control Loops, Classical PID Control, Synthesis of SISO Controllers.

MODULE-II

Fundamental Limitations in SISO Control, Model error Limitations, Structural Limitations, and Frequency Domain design limitations, Architectural Issues in SISO Control.

MODULE-III

Internal Model Principle, Feed forward and Cascade Control, Anti-wind-up scheme, SISO controller Parameterizations, Control Design Based on Optimization, Synthesis via state space methods.

MODULE-IV

Digital Computer Control, Models for sampled Data Systems, Sample Data Design, Internal Model Principle for Digital Control, Models for hybrid Control, Systems, Analysis of Inter sample behavior.

MODULE-V

MIMO Control Essentials, Analysis of MIMO Control Loops, Exploiting SISO Techniques in MIMO Control, MIMO Control Design: Design via Optimal control techniques, MIMO Controller Parameterizations, Decoupling.

Books:

1. Graham C. Goodwin, Stefan F.Graebe, Mario E.Salgado, "*Control System Design*", PHI-2002.

2. M. Athans and P. Falb, "*Optimal control*", MGH

3. K. Astrom, and B.wittenmark, "*Computer Control Systems: Theory and design*", Prentice Hall

Course Outcomes:

Upon completion of the course, students will be able to:

CO1	Analyze and design different SISO control loops.
CO2	Develop model predictive control to appropriate field.
CO3	Develop digital control and hybrid control models.
CO4	Express SISO controller design based on optimization and parameterization.
CO5	Analyze MIMO control loops and design MIMO control structure based on model predictive control.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Electric and Hybrid Vehicles

Module-I (5 hours)

Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies. Conventional Vehicles: Basics of vehicle performance, vehicle power source characterization, transmission characteristics, mathematical models to describe vehicle performance. Architectures of HEVs, series and parallel HEVs, complex HEVs.

Module-II (10 hours)

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

Module-III (10 hours)

Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives. Energy Storage: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Hybridization of different energy storage devices.

Module-IV (7 hours)

Power Electronics in HEVs: Rectifiers used in HEVs, voltage ripples; Buck converter used in HEVs, non-isolated bidirectional DC-DC converter, regenerative braking, voltage source inverter, current source inverter, isolated bidirectional DC-DC converter, PWM rectifier in HEVs, EV and PHEV battery chargers.

Electric Machines and Drives in HEVs: Induction motor drives, Field oriented control of induction machines; Permanent magnet motor drives; Switched reluctance motors; doubly salient permanent magnet machines. Case studies.

Module-V (7 hours)

Communications, supporting subsystems: In vehicle networks- CAN, Energy Management Strategies: Introduction to energy management strategies used in hybrid and electric vehicles, classification of different energy management strategies, comparison of different energy management strategies

Recommended Books

[1]. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.

[2]. Mehrdad Ehsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.

[3]. Mi Chris, Masrur A., and Gao D.W., " Hybrid Electric Vehicle: Principles and Applications with Practical Perspectives".

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Analyze the requirements and architecture of EVs and HEVs.
CO2	Analyze drive trains used in EVs and HEVs.
CO3	Demonstrate electric propulsion unit and storage systems for EVs and HEVs.
CO4	Develop drive systems for EVs and HEVs.
CO5	Analyze different communication systems used in EVs and HEVs.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Power Electronics and Drives Lab-I

LIST OF EXPERIMENTS

1. Simulation and discussion of 1-phase, controlled bridge rectifier with R, R-L and R-L-E load.

2. Simulation and discussion on effect of source inductance on current commutation of 1-phase, controlled bridge rectifier with R, R-L and R-L-E load.

3. Simulation of 3-phase, controlled bridge rectifier with R, R-L and R-L-E load.

4. Simulate and to study the effect of source inductance on current commutation 3-phase bridge rectifier with R, R-L and R-L-E load.

5. Analysis of full-wave converter based DC Motor Drives (1-phase and 3-phase)

6. Simulation of Buck, Boost and to study boundary between continuous and discontinuous conduction.

7. Simulation of Buck-Boost and to study boundary between continuous and discontinuous conduction.

8. Analysis of Chopper Fed DC motor Drive

9. Simulation of single phase inverter with PWM controller.

10. Analysis of three phase inverters.

11. Simulation of single phase AC voltage controllers.

12. Simulation of Speed control of DC motor using three phase fully controlled converter.

13. SPICE simulation of single phase inverter with PWM control.

14. SPICE simulation of single phase AC voltage controller using R, R-L and R-L-E loads.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Compile component library of MATLAB/SIMULINK and SPICE environment and develop code for equation based simulation.
CO2	Demonstrate the simulation of AC-DC power conversion and analyze the waveforms.
CO3	Demonstrate the simulation of DC-DC power conversion and analyze the waveforms.
CO4	Demonstrate the simulation of DC-AC power conversion and analyze the waveforms
CO5	Demonstrate the simulation of power electronic components using PSIM.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	3
CO2	3	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	3

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	3	3	3	3

Second Semester

Program Core Courses

Power Electronic Converters-II

MODULE-I (8 HOURS)

Converters for Static Compensation.Standard Modulation Strategies - Programmed Harmonic Elimination. Multi-Pulse Converters and Interface Magnetics.Multi-Level Inverters of Diode Clamped Type and Flying Capacitor Type and suitable modulation strategies -Space Vector Modulation - Minimum ripple current PWM method.Multi-level inverters of Cascade Type. Current Regulated Inverter -Current Regulated PWM Voltage Source Inverters.

MODULE-II (8 HOURS)

Methods of Current Control Hysteresis Control.Variable Band Hysteresis Control.Fixed Switching Frequency Current Control Methods.Switching Frequency Vs accuracy of Current Regulation.Areas of application of Current Regulated VSI

Switched Mode Rectifier - Operation of Single/Three Phase Bridges in Rectifier Mode.ControlPrinciples.Control of the DC Side Voltage, Voltage Control Loop. The inner Current Control Loop.

MODULE-III (8 HOURS)

Special Inverter Topologies - Current Source Inverter.Ideal Single Phase CSI operation, analysis and waveforms - Analysis of Single Phase Capacitor Commutated CSI.SeriesInverters.Analysis of Series Inverters.Modified Series Inverter.Three Phase Series Inverter.

MODULE-IV (8 HOURS)

Buck, Boost, Buck-Boost SMPS Topologies. Basic Operation- Waveforms - modes of operation-Output voltage ripple Push-Pull and Forward Converter Topologies - Basic Operation. Waveforms - Voltage Mode Control.Half and Full Bridge Converters.BasicOperation and Waveforms- Fly back Converter .discontinuous mode operation. Waveforms.Control-Continuous Mode Operation.Waveforms

MODULE-V (7 HOURS)

Introduction to Resonant Converters.Classification of Resonant Converters.Basic Resonant Circuit Concepts.Load Resonant Converter.Resonant Switch Converter.Zero Voltage Switching Clamped Voltage Topologies.Resonant DC Link Inverters with Zero Voltage Switching. High Frequency Link Integral Half Cycle Converter

BOOKS

[1]. Ned Mohan et.al: Power Electronics John Wiley and Sons

[2]. Rashid: Power Electronics Prentice Hall India

[3]. G.K.Dubey et.al: Thyristorised Power Controllers, Wiley Eastern Ltd.

COURSE OUTCOMES:

Upon completion of the subject the students will demonstrate the ability to:

CO1	Implement the standard modulation strategies for harmonic elimination using Multi-pulse and multi level inverters and concept of space vector modulation.
CO2	Evaluate the importance of current regulation in VSI and operation of Switch mode converters in rectification mode.
CO3	Demonstrate the principles of operation of current source inverters and series inverters, with circuit diagrams and waveforms.
CO4	Analyze DC-DC converters operating both in continuous and discontinuous mode of operation and design different topologies of Switch Mode Power Supplies (SMPS)
CO5	Aanalyze the operation of various types of resonant converters.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Advanced Machine Drives

Module 1

Stepper Motor: Introduction, Types, Hybrid stepper motor- construction, principle of operation, two phases energized at a time, conditions for operation, different configurations, VR Stepper motor- single stack and multi stack, Drive systems and circuit for open loop and Closed loop control of stepping motor. Dynamic characteristics.Single phase stepper Motor, Expression of voltage, current and torque for stepper motor and criteria for synchronization.

Module 2

Switched Reluctance Motor: Constructional features, principle of operation, Design Aspects and profile of the SRM, Torque equation, Power converters and rotor sensing mechanism, expression of torque and torque-speed characteristics

Module 3

Permanent magnet materials, properties, minor hysteresis loop and recoil line, equivalent circuit, stator frames with permanent magnets,

Module 4

Brushless DC Motor: Construction, operation, sensing and switching logic scheme, Drive and power circuit, Theoritical analysis and performance prediction, transient Analysis.

Module 5

 Linear Induction Motor: Construction and principle of operation of Linear Induction Motor, Approximate calculation of the force on rotor.

Text Book:

 1. Vekatratnam, "Special Electrical Machines", Universities Press

 Reference:

1 Fitzerald and Kingsley," Electrical Machines" McGraw Hill.Miller. T. J. E., "Brushless Permanent Magnet and Reluctance Motor Drives", Clarendon Press, Oxford, 1989.

2. Kenjo. T and Nagamori. S, "Permanent Magnet and Brushless DC Motors", Clarendon Press, Oxford, 1989.

3. Kenjo. T, "Stepping Motors and their Microprocessor Control", Clarendon Press, Oxford, 1989

4. Krishnan R, "Switched Reluctance Motor Drives", Modelling, Simulation, Analysis, Design and applications, CRC press

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

CO1	Analyze Stepper Motor, its type, control and principle of operation, dynamic characteristics
CO2	Analyze Switched Reluctance Motor, construction , principle of operation, speed torque characteristics
CO3	Analyze permanent magnet material and its properties
CO4	Analyze construction, principle of operation of BLDC motor
CO5	Analyze construction, principle of operation of Linear Induction Motor

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Program Elective-III

Industrial Load Modeling and Control

Module I

MODELING OF PHASE CONTROL OF DC DRIVES (10)

Motor-drives, load torque-speed characteristics, power devices and switches, modeling of DC motor-load- block diagram and transfer function for armature and field control, phase controlled dc motor drives-single phase and three phase controlled converters, control circuit, current source with three phase controlled converter, four quadrant operation, steady state analysis of three phase converter, speed control of two quadrant dc motor drives.

Module II

CHOPPER CONTROL OF DC MOTOR DRIVES (8)

Principle of operation of the chopper, Steady-state analysis of Chopper-controlled dc motor drive, Continuous Current Conduction, Discontinuous Current Conduction, Closed-loop operation, Pulse-Width-Modulated Current Controller, Hysteresis-Current Controller, dynamic analysis of the speed-controlled dc motor drive.

Module III

CONTROL OF INDUCTION MOTOR DRIVES (10)

Steady state performance equations of the induction motor, dynamic modeling of induction machines, phase-controlled induction-motor drives- stator voltage control, Closed-Loop Operation, Closed loop control of slip-energy recovery scheme, Pulsating torque, Static Scherbius Drive, frequency-controlled induction motor drives, VSI and CSI fed V/f and PWM control scheme of induction motor drive system.

Module IV

CONTROL OF SYNCRONOUS AND BLDC MOTOR DRIVES (8)

True mode and Self-control of synchronous motor–Torque control, Power factor control– Brushless excitation systems, Sinusoidal and trapezoidal type of Brushless dc motors – Block diagram of current controlled Brushless dc motor drive.

Module V VECTOR CONTROL OF INDUCTION MOTOR DRIVE (10)

Principle of vector control of IM - Direct vector control – Indirect vector control with feedback - Indirect vector control with feed-forward - Indirect vector control in various frames of reference, Decoupling of vector control with feed forward compensation – Direct Torque Control of IM.

Recommended Books

1..R.Krishnan,, Electric Motor Drives - Modeling, Analysis and Control Prentice- Hall of India Pvt. Ltd., New Delhi, 2003.

2.Dubey, G.K, Power semiconductor controlled devices, Prentice Hall International New jersey, 1989.

3. Ned Mohan, "Power Electronics and drives", Wiley 2006

4.Bimal K. Bose, Modern Power Electronics and AC Drives, Pearson Education (Singapore) Pte. Ltd., New Delhi, 2003.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Express the modeling and closed loop control of DC motor-load drives using phase control.
CO2	Express the modeling and closed loop control of DC motor-load drives using DC-DC chopper control.
CO3	Express the modeling and closed loop control of Induction motor drives using phase control.
CO4	Analyze the operation of Synchronous motor and BLDC machines, torque control using current and flux controllers.
CO5	Analyze direct and indirect vector control on induction motors.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Special Electrical Machines

MODULE I: (08 Hours)

Permanent Magnet Brushless DC Motors Fundamentals of Permanent Magnets- Types- Principle of operation- Magnetic circuit analysis- EMF and Torque equations- Characteristics and control.

MODULE II: (08 Hours)

Permanent Magnet Synchronous Motor Principle of operation – EMF and Torque equations - Phasor diagram – Power controllers – Torque speed characteristics – Digital controllers – Constructional features, operating principle and characteristics of synchronous reluctance motor.

MODULE III: (09 Hours)

Switched Reluctance Motors Constructional features –Principle of operation- Torque prediction–Characteristics Power controllers – Control of SRM drive- Sensor less operation of SRM – Applications.

MODULE IV: (10 Hours)

 STEPPER MOTORSConstructional features –Principle of operation –Types – Torque predictions – Linear and Nonlinear analysis – Characteristics – Drive circuits – Closed loop control –Applications. High-Speed Operation of Stepper-Motors: Pull-out torque/speed, characteristics of Hybrid stepper motors, calculation of pull-out torque, pull-out torque/speed characteristics for the VR stepper motors, calculation of the pull out torque.

MODULE V: (07 Hours)

OTHER SPECIAL MACHINES-Principle of operation and characteristics of Hysteresis motor – AC series motors – Linear motor Basic principle of operation and types; End effects & transverse edge effects; Field analysis & Propulsion force; equivalent circuit. – Applications.

BOOKS:

1) T.J.E. Miller, 'Brushless magnet and Reluctance motor drives', Claredon press, London, 1989.

2) R.Krishnan, 'Switched Reluctance motor drives', CRC press, 2001.

3) T.Kenjo, 'Stepping motors and their microprocessor controls', Oxford University press, New Delhi, 2000.

Course Outcomes:

Upon completion of the course, the students will:

CO1	Evaluate the fundamental concepts of permanent magnets and the operation of permanent magnet brushless DC motors
CO2	Evaluate the concepts of permanent magnet brushless synchronous motors and synchronous reluctance motors
CO3	Develop the control methods and operating principles of switched reluctance motors
CO4	Demonstrate the concepts of stepper motors and its applications
CO5	Express the basic concepts of other special machines

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Advanced Digital Signal Processing

Module-I (8 hours)

Discrete time signals, systems and their representations: Discrete time signals (Linear Time Invariant systems, Stability and causality).

Discrete Fourier Transform: Properties of different transforms, Linear convolution using DFT- Computation of DFT.

Module-II (8 hours)

Digital filter design and realization structures: Design of IIR digital filters from analog filters, Impulse invariance method and Bilinear transformation method, FIR filter design using window functions, Comparison of IIR and FIR digital filter, Basic IIR and FIR filter realization structures, Signal flow graph representations.

Module-III (8 hours)

Finite Word-Length Effects on Digital Filter: Analysis of finite word-length effects Quantization process and errors, Coefficient quantization effects in IIR and FIR filters, A/D conversion noise- Arithmetic round-off errors, Dynamic range scaling, Overflow oscillations and zero input limit cycles in IIR filters.

Module-IV (7 hours)

Statistical digital signal processing: Linear Signal Models All pole, All zero and Pole-zero models, statistical properties of random signal.

Module -V (8 hours)

Power spectrum estimation: Spectral analysis of deterministic signal, Estimation of power spectrum of stationary random signals, Optimum linear Filters, Optimum signal estimation, Mean square error estimation, Optimum FIR and IIR filters.

TEXT BOOKS

[1]. John G. Proakis, and Dimitris G. Manolakis, "Digital Signal Processing" (third edition), Prentice-Hall of India Pvt. Ltd, New Delhi, 1997

[2]. Alan V. Oppenheim, Ronald W. Schafer, "Discrete-Time Signal Processing", Prentice-Hall of India Pvt. Ltd., New Delhi, 1997

REFERENCE BOOKS

[1] A. NagoorKani, "Digital Signal Processing", Second edition, McGraw Hill.

[2]. Sanjit K Mitra, "A computer-based approach", Tata Mc Grow-Hill edition .1998

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Express the basic concept of Digital Signal Processing, Discrete Fourier Transform and its application.
CO2	Evaluate Digital filter design and its structural realization.
CO3	Organize the errors of word length effect and their correction techniques.
CO4	Expressof Statistical digital signal processing.
CO5	Develop the knowledge of Power spectrum estimation.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Program Elective-IV

FACTS and Custom Power Devices

Module-I (8 hours)

FACTS concepts and general system considerations: Power flow in AC system, transient stability and dynamic stability, basic description of FACTS controllers, brief review of voltage sourced converter and current sourced converter, modelling philosophy.

Module-II (8hours)

Static var compensator (SVC and STATCOM): objectives of shunt compensation, methods of controllable Var Generation, regulation slope, transfer function, V-I and V-Q characteristics, transient stability enhancement, var reserve control, conventional power flow models, shunt variable susceptance model, firing angle model, transient stability model, voltage magnitude control using SVC & STACOM, Application example.

Module-III (8 hours)

Static Series compensators (TCSC and SSSC): objectives of series compensation, improvements of voltage and transient stability, power oscillation damping, sub-synchronous damping, transmittable power and transmittable angle characteristics, control range, conventional power flow models, variable series impedance model, firing angle model, transient stability model, active power flow control using TCSC & SSSC, Application example.

Module-IV: (8 hours)

Static voltage and phase angle regulator (TCVR and TCPAR): objectives of voltage and phase angle regulators, approaches to TCVR and TCPAR, switching converter based voltage and phase angle regulators, Unified power flow controller: Basic operating principles, transmission control, independent real and reactive power flow control, power flow models, transient stability model, control structure, basic control system for P and Q control, dynamic performance, Application example.

Module-V (7 hours)

Brief control studies such as Steady state analysis and control, EMTP studies, power oscillation stability analysis and control, transient stability control.

Recommended Books

1. Y. H. Songs, A. T. Johns, "Flexible AC Transmission Systems", IEE Press, 1999
2. N. G. Hingorani, L. Gyugyi, "Understanding FACTS", IEEE Press, Indian Edition, 2001.
3. E. Acha, "FACTS: Modellingand Simulation in Power Networks", John Wiley & Sons, 2004.
4. K. R. Padiyar ,"FACTS Controllers in Power Transmission & Distribution", New Age International Publishers.
5. Vijay K. Sood, "HVDC and FACTS Controller: Applications of Static Converters in Power Systems", Kluwer Power Electronics & Power System Series, 2006.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Evaluate the basic philosophy of FACTS devices and modelling and control aspect of FACTS devices...
CO2	Analyze fundamental function of SVC and STATCOM.
CO3	Analyze power system operation with TCSC and SSSC.
CO4	Evaluate power flow control using TCVR, TCPAR and UPFC.
CO5	Express comprehensive control of power system using FACTS devices.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Industrial Automation and Control

MODULE-I

Introduction to process dynamics, its type and classifications. Control actions and controller tuning: Basic control actions-on/off, P, P+I, P+I+D, floating control, pneumatic and electronic controllers, pneumatic vs hydraulic control, controller tuning.

MODULE-II

Introduction to PLC, PAC, DCS and SCADA.IEDs, RTUs, HMI, Smart Sensors and Actuators. IEEE 802.11 / 15 Standards, IEEE 1451.5 Std. Communication Networks for PLC. The Instrument Lists of PLC and HMI.Sequential and Programmable controllers, System Architecture, Programming languages of PLC, Relay logic and Ladder logic, Ladder Diagram Elements.

MODULE-III

Computer controlled processes: PLC based control of different types of processes such as liquid level system and flow control, open-and-closed chamber pressure control, temperature control, different types of heat exchangers, control of pressurized gases.

MODULE-IV

Physical Ladder Diagram and Programmable Ladder Diagram.Different Modules of the System Architecture of PLC. Case Studies: frost free refrigerator / freezer system; composite discrete / continuous control; conveyor system; oven system; elevator system; uniformly heated liquid control system, and hydro-phonic system.

MODULE-V

Advances in Automation: Programmable Automation Controllers. NI my-DAQ, my-RIO, c-RIO, and ELVIS.Role of Internet of Things and Cyber Physical System in Industry Automation, MQTT protocol.

Books:

1. Peter D. Harriot, "Process Control", Tata McGraw-Hill, New Delhi, 2009.

2. Liptak, "Process Control: Instruments Engineer's Handbook", Butterwirth Heinemann, 1995.

3. Curtis D. Johnson, "Process Control and Industrial Technology", Pearson India, 8th ed., 2012.

Reference books:

1. Norman A Anderson, Instrumentation for Process Measurement and Control, CRC Press, 2008.

2. B. Wayne Bequette, "Process Control – Modeling, Design, and Simulation", Pearson India, 2015.

3. John W. Webbs, "Programmable Logic Controllers – Principals and Applications", fifth Edition, Pearson India /PHI (Old edition), 2012.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Analyze the basic principles and importance of process control applications using automation;
CO2	Develop the knowledge of the P&ID, the Instrumentation Lists, and final elements to ensure that well-tuned control is achieved;
CO3	Develop a sound foundation for students in control systems, automation platforms through a diverse range of theoretical skills and practical experience of real time applications;
CO4	Implement planning, designing, installing, controlling and maintenance of different process and automated applications using PLCs/PACs. Further, PLC / PAC algorithm using Ladder Logic Diagram or equivalent languages while handling a plant process;
CO5	Implement automation platform such as PACs and IoT while handling a plant process.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Embedded Systems

Module 1

Introduction to embedded system -Definition and Classification, Design challenges, Optimizing design metrics, time to market, applications of embedded systems and recent trends in embedded systems, memory management, Overview of Processors and hardware units in an embedded system, Software embedded into the system, communication protocols like SPI, I2C, CAN etc.

Module 2

Introduction to ARM core architecture, ARM extension, family, Pipeline, memory management, Bus architecture, Programming model, Registers, Operating modes, instruction set, Addressing modes, memory interface.

Module 3

Study of on-chip peripherals – Input/ output ports, Timers, Interrupts, on-chip ADC, DAC, RTC modules, WDT,PLL, PWM,USB, I2C, SPI, CAN etc.

Module 4

Need of interfacing, interfacing techniques, interfacing of different displays including Graphic LCD, controlling a DC motor using PWM, Keypad controllers, stepper motor controllers.

Module 5 Definitions of process, tasks and threads, I/O Subsystems, Interrupt Routines Handling in RTOS, RTOS Task scheduling models, Handling of task scheduling and latency and deadlines as performance metrics, Co-operative Round Robin Scheduling, Case Studies of Programming with RTOS. ARM926EJ-S, Features, Specifications (LPC314x /LPC315x As reference controllers)

BOOKS:

1) Embedded Systems Architecture, Programming and Design, Rajkamal, TATA McGraw-Hill, First reprint Oct, 2003.

2) Embedded Systems Design, Second Edition, Steve Heath, Elsevier India Pvt. Ltd. 2007.

3) Andrew Sloss, AndewSloss, "ARM System Developers Guide"

4) Introduction to Embedded systems, Shibu K V, Tata McGraw Hill First print – 2009.

5) An Embedded Software Primer, David E,Simon, Pearson Education Asia, 2000.

6) Embedded Systems Design, A unified Hardware /Software Introduction, Frank Vahid and Tony Givargis, John Wiley, 2002.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Express embedded systems and the different embedded system design technologies and Analyze the various metrics or challenges in designing an embedded system;
CO2	Develop the idea of the architecture of the ARM processor and its programming aspects;
CO3	Develop the ability to understand the internal architecture Processor LPC 2148;
CO4	Analyze key concepts of embedded systems like IO, timers, interrupts, interaction with peripheral devices;
CO5	Implement real time embedded systems using the concepts of RTOS and to analyse various examples of embedded systems based on ARM processor.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Power Electronics and Drives Lab-II

LIST OF EXPERIMENTS

1. Analysis of Dual Converter fed DC motor Drive.

2. Analysis of Vector Controlled Induction Motor Drive.

3. Analysis of 3-phase to 3-phase cycloconverter.

4. Analysis of three phase inverters.

5. Analysis of chopper fed DC motor drive.

6. Analysis of closed loop speed control of BLDC Motor.

7. Analysis of closed loop speed control of Switched Reluctance Motor drive.

8. Direct torque control of Induction Motor drive.

9. Speed control of Induction Motor using Cycloconverter.

10. Speed control of DC motor using 3-phase rectifier.

11. Speed control of universal motor using 1 phase full controlled converter.

12. SPICE simulation of resonant pulse circuit.

13. PSIM simulation of PWM inverter fed induction motor drives.

14. PSIM simulation of V/f control of induction motor drives.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Analyze and design DC motor drives
CO2	Analyze and design induction motor drives
CO3	Analyze and design IGBT based inverters.
CO4	Analyze and design BLDC Motor and Switched Reluctance Motor drives.
CO5	Implement PSIM based simulation of induction motor drives.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	3
CO2	3	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	3

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	3	3	3	3

Minor Project and Seminar

Course description:

As a part of the curriculum, this is a sessional course, in which the students are trained in basic tools and presentation skills.

Upon completion of the course, the students will demonstrate the ability to:

CO1	Identify and analyze engineering problems and research problem.
CO2	Utilize technical resources for problem solving.
CO3	Develop skills to use modern engineering tools, software and equipment.
CO4	Write technical reports and demonstrate the findings in terms of oral presentations.
CO5	Develop confidence plan for future work .

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	3
CO2	3	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	3

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	3	3	3	3	3	3

Third Semester

Program Elective-V

Smart Power Grids

Module-I (6 hours)

Introduction to Smart Grid, Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Concept of Robust & Self-Healing Grid, Present development & International policies in Smart Grid.

Module-II (8hours)

Introduction to Smart Meters, Real Time Pricing, Smart Appliances, Automatic Meter Reading (AMR), Outage Management System (OMS), Plug in Hybrid Electric Vehicles (PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation, Smart Substations, Substation Automation, Feeder Automation.

Module-III (7 hours)

Geographic Information System (GIS), Intelligent Electronic Devices (IED) & their application for monitoring & protection, Smart storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage, Wide Area Measurement System (WAMS), Phase Measurement Unit (PMU).

Module-IV (10 hours)

Concept of micro-grid, need & applications of micro-grid, Formation of micro-grid, Issues of interconnection, Integration of renewable energy sources, Protection & control of micro-grid. Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.

Module-V (7 hours)

Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighbourhood Area Network (NAN), Wide Area Network (WAN), Bluetooth, ZigBee, GPS, Wi-Fi, Wi-Max based communication, Wireless Mesh Network, Basics of CLOUD Computing & Cyber Security for Smart Grid, Broadband over Power line (BPL), IP based protocols.

Suggested reading:

1. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, "*Smart Grid: Technology and Applications*", Wiley 2012.

2. Clark W. Gellings, "*The Smart Grid: Enabling Energy Efficiency and Demand Response*", CRC Press, 2009.

3. Ali Keyhani, "*Design of smart power grid renewable energy systems*", Wiley-IEEE, 2011.

4. Stuart Borlas'e, "*Smart Grid: Infrastructure, Technology and solutions*", CRC Press.

5. A.G.Phadke, "*Synchronized Phasor Measurement and their Applications*", Springer.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Evaluate the difference between smart grid & conventional grid.
CO2	Express smart metering concepts to industrial and commercial installations.
CO3	Organize solutions in the areas of smart substations, distributed generation and wide area measurements& PMUs.
CO4	Plan solutions for the problems associated with integration of distributed generations.
CO5	Apply smart grid solutions using AMI and modern communication technologies.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Machine Learning and AI

MODULE-I (10 HOURS)

Principles of AI and Search Techniques: Introduction to AI, AI Problems, Planning, Production System, State Space Representation, Branches and Application of AI

Heuristic Search: Hill Climbing, Simulated Annealing, Depth First Search, Breadth First Search, Greedy Method, Best First Search, A* Algorithm, Problem Reduction: AND-OR graph, AO* Algorithm, Adversary Search: MINIMAX Algorithm, Alpha-Beta Cut-off algorithm.

MODULE-II (10 HOURS)

Knowledge and Reasoning: Knowledge Management, Types of Knowledge, Knowledge Representation, First Order Logic: Basic Predicate Representation, Conversion of WFF to Clause Form, Resolution and its Problem,

Reasoning: Types of Reasoning, Non-Monotonic Inference Method and Reasoning, Truth Maintenance System, Rule Based Reasoning, Reasoning with Fuzzy Logic

MODULE-III (10 HOURS)

Machine Learning (ML): Introduction to ML, Problems in ML, Learning System, Application of ML, Clustering: k-Means Clustering, Fuzzy and Hierarchical Clustering, Reinforcement Learning: Markov Decision Problem, Q-learning, Temporal Difference Learning, Statistical Learning: Hidden Markov Models, Linear, Quadratic Classifier, Decision Trees, Bayesian Networks

MODULE-IV (6 HOURS)

Artificial Neural Network: ANN, Types of Network, Perceptron, RBF Network, Supervised Learning: Support Vector Machines, Inductive Logic Programming, Case-Based Reasoning, Ensemble Classifier, Nearest Neighbourhood, Fuzzy Network, RBF, Unsupervised Learning: Self Organising Maps, Adaptive Resonance Theory, Deep Learning

MODULE-V (3 HOURS)

Expert System: Characteristic and Components Expert System, Expert System Development, Application of Expert System

TEXT BOOKS

[1]. E. Rich and K. Knight, *Artificial Intelligence*, Tata McGraw Hill.

[2]. Tom Mitchell, *Machine Learning*, McGraw Hill , 1997, ISBN 0-07-042807-7

REFERENCE BOOKS

[1]. S. Russel and P. Norvig, *Artificial Intelligence: a Modern Approach*, Pearson

[2]. Zsolt Nagy, Artificial Intelligence and Machine Learning Fundamentals

Course Outcomes:

Upon successful completion of this course, students will be able to

CO1	Analyze the principles, advantages, problem of AI and implement in real field with different algorithms.
CO2	Construct solutions of problems using AI Knowledge and Reasoning.
CO3	Analyze the principles, advantages, problems of ML and applications of ML.
CO4	Analyze the principles of Artificial Neural Network and the different learning algorithm and deep learning.
CO5	Analyze the characteristics, components and development of Expert System.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Nonlinear Dynamics

Module-I (8 hours)

One dimensional flows: Flows on the line, fixed points and stability, Linear stability analysis, existence and uniqueness, Potentials. Bifurcations: Saddle-node, Transcritical, Pitchfork bifurcations, Imperfect bifurcations and catastrophe. Flows on the circle.

Module-II (8 hours)

Two dimensional flows: Linear systems, classification. Phase plane: phase portraits. Existence, uniqueness and topological consequence, fixed points and linearization.Conservative and reversible systems.Index theory.

Module-III (8 hours)

Limit cycles: Introduction, examples, Ruling out closed orbits. Poincare-Bendixson theorem, Lienard systems, Relaxation oscillators, Weakly non-linear oscillators.
Bifurcations: Saddle-node, Transcritical and Pitchfork bifurcations in two dimensions. Hopfbifurcations.Global bifurcations of cycles.Quasiperiodicity.

Module-IV (8 hours)

Lorentz equations: Introduction, a chaotic waterwheel, simple properties, chaos on a strange attractor, Lorentz map, exploring parameter space.
One dimensional maps: Introduction, fixed points and cobwebs, Logistic map, Periodic windows, Liapunov exponent, Universality and experiments.

Module-V (7 hours)

Fractals: countable and uncountable sets, Cantor set, Dimension of self-similar fractals, Box dimension, Point wise and correlation dimensions.
Strange Attractors: Introduction, Henon Map, Rossler systems, Attractor reconstruction

Recommended Books

[1].   Steven H. Strogatz, Nonlinear Dynamics and Chaos, Levant publications.

[2].   M Vidyasagar, "Nonlinear Systems Analysis", Prentice Hall.

[3].   R Seydel, "Practical Bifurcation and Stability Analysis", Springer Verlag.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Analyze one dimensional flows on the line and circle.
CO2	Analyze two dimensional flows of linear systems and phase plane.
CO3	Analyze limit cycles and bifurcations in two dimensions.
CO4	Analyze Lorentz equations and one-dimensional maps.
CO5	Analyze fractals and strange attractors.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

SCADA System and Applications

Module-1 (8 hours)

Introduction to SCADA Data acquisition systems- Evolution of SCADA, Communication technologies-.Monitoring and supervisory functions- SCADA applications in Utility Automation, Industries.

Module-2 (8 hours)

SCADA System Components: Schemes- Remote Terminal Unit (RTU), Intelligent Electronic Devices (IED), Programmable Logic Controller (PLC), Communication Network, SCADA Server, SCADA/HMI Systems

Module-3 (8 hours)

SCADA Architecture: Various SCADA architectures, advantages and disadvantages of each system - single unified standard architecture -IEC 61850-SCADA

Module-4 (8 hours)

Communication: Various industrial communication technologies -wired and wireless methods and fibre optics-Open standard communication protocols

Module-5 (8 hours)

SCADA Applications: Utility applications- Transmission and Distribution sector - operations, monitoring, analysis and improvement. Industries - oil, gas and water. Case studies, Implementation. Simulation Exercises

Books

1. Stuart A Boyer. SCADA-Supervisory Control and Data Acquisition', Instrument Society of America Publications. USA. 1999.

2. Gordan Clarke, Deon RzynAzvs,Practical Modern SCADA Protocols: DNP3, 60870J and Related Systems', Newness Publications, Oxford, UK,2004

Course Outcomes:

Upon completion of the course, students will demonstrate the ability to:

CO1	Express the basic tasks of Supervisory Control Systems (SCADA) as well as their typical applications
CO2	Express about SCADA system components: remote terminal units, PLCs, intelligent electronic devices, HMI systems, SCADA serve
CO3	Develop knowledge about SCADA architecture, various advantages and disadvantages of each system
CO4	Develop knowledge about single unified standard architecture IEC 61850
CO5	Express knowledge about SCADA applications in transmission and distribution sector, industries etc

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Open Elective

Non-linear System Theory

Module-I (8 hours)

One dimensional flows: Flows on the line, fixed points and stability, Linear stability analysis, existence and uniqueness, Potentials. Bifurcations: Saddle-node, Transcritical, Pitchfork bifurcations, Imperfect bifurcations and catastrophe. Flows on the circle.

Module-II (8 hours)

Two dimensional flows: Linear systems, classification. Phase plane: phase portraits. Existence, uniqueness and topological consequence, fixed points and linearization.Conservative and reversible systems.Index theory.

Module-III (8 hours)

Limit cycles: Introduction, examples, Ruling out closed orbits. Poincare-Bendixson theorem, Lienard systems, Relaxation oscillators, Weakly non-linear oscillators.

Bifurcations: Saddle-node, Transcritical and Pitchfork bifurcations in two dimensions. Hopfbifurcations.Global bifurcations of cycles.Quasiperiodicity.

Module-IV (8 hours)

Lorentz equations: Introduction, a chaotic waterwheel, simple properties, chaos on a strange attractor, Lorentz map, exploring parameter space.

One dimensional maps: Introduction, fixed points and cobwebs, Logistic map, Periodic windows, Liapunov exponent, Universality and experiments.

Module-V (7 hours)

Fractals: countable and uncountable sets, Cantor set, Dimension of self-similar fractals, Box dimension, Point wise and correlation dimensions.

Strange Attractors: Introduction, Henon Map, Rossler systems, Attractor reconstruction

Recommended Books

[1].   Steven H. Strogatz, Nonlinear Dynamics and Chaos, Levant publications.

[2].   M Vidyasagar, "Nonlinear Systems Analysis", Prentice Hall.

[3].   R Seydel, "Practical Bifurcation and Stability Analysis", Springer Verlag.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Develop one dimensional flows on the line and circle.
CO2	Develop two dimensional flows of linear systems and phase plane.
CO3	Express limit cycles and bifurcations in two dimensions.
CO4	Construct Lorentz equations and one-dimensional maps.
CO5	Demonstrate fractals and strange attractors.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Operations Research

Module-I (8 hours)
Statement of an optimization problem, classical optimization techniques: single variable optimization, unconstrained and constrained multivariable optimization problems, Karush-Kuhn-Tucker (KKT) conditions, convex programming problem.
Linear programming problem, simplex algorithm, duality, transportation model and its variants.Linear programming solvers in MATLAB, SCILAB and OCTAVE.

Module-II (8 hours)
Nonlinear programming algorithms: direct search method, gradient method, separable programming, quadratic programming, chance constrained programming. Non-linear programming solvers in MATLAB, SCILAB and OCTAVE.

Module-III (8 hours)
Overview of the geometric programming problem. Dynamic programming: multi-stage decision process, computational procedure. Integer programming: solution using cutting-plane method, branch-and-bound method. Mixed-integer programming problems.

Module-IV (8 hours)
Stochastic processes: review of basic probability, empirical distributions, Monte carlo simulation. Generation of discrete and continuous random variables, joint distribution and copula.Decision making under certainty, risk and uncertainty, game theory.Markov chains.

Module-V (7 hours)
Multiobjective optimization: pareto optimality, selection using fuzzy membership, weighting method, utility function method, global criterion method, goal programming method. Concept of heuristic and meta-heuristic methods, Derivative free optimization, Genetic algorithms, neural networks, swarm optimization techniques.

Books
1. S.S.Rao, "Engineering Optimization", 3rd Ed.,New Age International (P) Ltd,New Delhi, 2007
2. H.A. Taha, Operations Research, An Introduction, PHI, 2008

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Apply classical optimization and linear programming techniques
CO2	Construct solutions for nonlinear programming problems.
CO3	Construct solutions for dynamic programming and integer programming problems.
CO4	Apply stochastic processes and tools for solving decision making problems
CO5	Apply multi-objective optimization and evolutionary programming techniques

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Industrial Safety

Module-I (8 hours)

Introduction to Industrial Safety Engineering, Key concepts and terminologies, Safety domain ontology, Risk Assessment & Control, Safety Engineering & Accident causing mechanisms, Preliminary Hazard List, Preliminary Hazard Analysis, Hazard and operability study (HAZOP), ailure Modes and Effects Analysis (FMEA)- Identification of Failure Modes.

Module-II (8 hours)

Fault tree and event tree analysis (qualitative & quantitative). Bow-tie and quantitative risk assessment (QRA).Safety function deployment

Module-III (8 hours)

Safety vs reliability – quantification of basic events (repair to failure, repair-failure-repair, and combined processes), Safety vs reliability – quantification of basic events (contd.).

Module-IV (8 hours)

Systems safety quantification (e.g., truth tables, structure functions, minimal cut sets).Human error analysis and safety

Module-V (7 hours)

Accident investigation and analysis, Application of virtual reality, OSHAS 18001 and OSHMS.

Recommended Books

[1]. "Industrial safety management", L M Deshmukh, TATA McGraw Hill, 2010.

[2]. "Occupational safety Manual" BHEL.

[3]. R Seydel, "Practical Bifurcation and Stability Analysis", Springer Verlag.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Develop key concepts and terminologies of industrial safety.
CO2	Constructfault tree and event tree analysis.
CO3	Evaluate safety versus reliability.
CO4	Implementsystems safety quantification.
CO5	Implementaccident investigation and analysis.

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Waste to Energy

Module-I (8 hours)

Solid Waste Sources Solid Waste Sources, types, composition, Properties, Global warming, Municipal Solid Waste: Physical, chemical and biological properties , Waste Collection and, Transfer stations, Waste minimization and recycling of municipal waste, Segregation of waste, Size Reduction , Managing Waste. Status of technologies for generation of Energy from Waste Treatment and Disposal Aerobic composting, incineration, Furnace type and design, Medical waste /Pharmaceutical waste treatment Technologies, incineration, Environmental impacts, Measures to mitigate environmental effects due to incineration .

Module-II (8 hours)

Land Fill method of Solid waste disposal Land fill classification, Types, methods and Sitting consideration, Layout and preliminary design of landfills: Composition, characteristics, generation, Movement and control of landfill leach ate and gases, Environmental monitoring system for land fill gases.

Module-III (8 hours)

Energy Generation from Waste Bio-chemical Conversion: Sources of energy generation, anaerobic digestion of sewage and municipal wastes, direct combustion of MSW-refuse derived solid fuel, Industrial waste, agro residues, Anaerobic Digestion.

Module-IV (8 hours)

Biogas production, Land fill gas generation and utilization, Thermo-chemical conversion: Sources of energy generation, Gasification of waste using Gasifiers, Briquetting, Utilization and advantages of briquetting, Environmental benefits of Bio-chemical and Thermo-chemical conversion.

Module-V (7 hours)

E-waste: e-waste in the global context – Growth of Electrical and Electronics Industry in India – Environmental concerns and health hazards – Recycling e-waste: a thriving economy of the unorganized sector – Global trade in hazardous waste – impact of hazardous e-waste in India. Management of e-waste: e-waste legislation, Government regulations on e-waste management – International experience – need for stringent health safeguards and environmental protection laws of India.

Books

1. Nicholas P. Cheremisinoff. Handbook of Solid Waste Management and Waste Minimization Technologies.An Imprint of Elsevier, New Delhi (2003).
2. Capareda S, Introduction to biomass energy conversion, CRC Press (2013).
3. Brown RC and Stevens C, Thermo-chemical Processing of Biomass: Conversion into Fuels, Chemicals and Power, Wiley and Sons (2011).

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Develop knowledge of technologies for generation of energy from solid waste
CO2	Analyze methods of solid waste disposal
CO3	Express knowledge on sources of energy from bio-chemical conversion
CO4	Analyze bio-gas production and gasification of wastes
CO5	Analyze methods for management of e-waste

Course Articulation Matrix

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

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Dissertation (Phase-I)

Course description:

As a part of the curriculum, this is a sessional course, in which the students are trained to perform literature review and formulate a research problem.

Upon completion of the course, the students will demonstrate the ability to:

CO1	Evaluate published literature and express the research gaps.
CO2	Construct a research problem.
CO3	Compile modern engineering tools, software and equipment and develop research methodology.
CO4	Write technical documents and give oral presentations related to the work completed.
CO5	Develop confidence for detailed analysis of the selected problem.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	3
CO2	3	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	3

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	3	3	3	3	3	3

Dissertation (Phase-II)

Course description:

As a part of the curriculum, this is a sessional course, in which the students are trained to analyze a research problem and develop the solution.

Upon completion of the course, the students will demonstrate the ability to:

CO1	Apply selected solution methodology to produce solutions to the chosen problem.
CO2	Analyze the output and demonstrate its validity.
CO3	Organize the results and compile the conclusions.
CO4	Write technical report and express the findings in oral presentations.
CO5	Develop confidence for identifying future scope and ability for life-long learning.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	3
CO2	3	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	3

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	3	3	3	3	3	3