SEMESTER I SYLLABUS

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22MA060B	LINEAR ALGEBRA AND OPTIMIZATION TECHNIQUES	DCC	3	0	0	3	2022

i) COURSE OBJECTIVES

1. Develop a conceptual basis for vector spaces and Linear algebra.
2. Equip the Students with a thorough understanding of various optimization techniques.

Ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Apply the concepts of vector spaces in various applications	Apply
CO 2	Apply orthogonality and matrix factorizations to solve appropriate problems	Apply
CO 3	Solve Linear programming Problems	Apply
CO 4	Solve Integer programming Problems	Apply
CO 5	Solve unconstrained and constrained optimization problems.	Apply

Iii) SYLLABUS

Vector spaces –subspaces-Basis-null space and column space- linear Transformations - orthogonality – least square solutions - matrix factorizations.

Linear programming problems - Simplex Methods –Two phase method-Duality-Dual Simplex Method-Integer programming.

Non-linear programming (Unconstrained and constrained) Kuhn-Tucker conditions-quadratic programming - Dynamic programming.

Iv) REFERENCES

1) David C. Lay, Linear Algebra, Pearson Education, 4th Edition 2012.
2) Kenneth Hoffman and Ray Kunze, Linear Algebra, Prentice-Hall, 2nd Edition.1978.
3) Seymour Lipschulz, Linear Algebra, Tata McGraw Hill,3rd Edition 2017.
4) Singiresu S Rao, Engineering Optimization Theory and Practice, 3rd Edition 2010.
5) K.V. Mittal and C. Mohan, Optimization Methods in Operations Research and System Analysis, New Age International Publishers,3rd Edition,2016.
6) Hamdy A. Taha, Operations Research an Introduction, PHI, 9th Edition, 2011.

v) COURSE PLAN

Module	Contents	No. of hours
I	Vector spaces and subspaces, null space and column space of a matrix; linearly independent sets and bases; Coordinate systems; dimension of a vector space; rank; change of basis; linear transformations– properties-kernel and range-computing kernel and range of a linear transformation.	10
II	Inner product, length and orthogonality; orthogonal sets; orthogonal projections; Gram Schmidt process; least square solutions - QR factorization; Singular value decomposition.	9
III	Linear Programming Problems-Simplex Methods – two phase simplex method – Duality - Dual simplex method. Integer linear programming; Graphical representation - Gomory's cutting plane method.	10
IV	Unconstrained non-linear Optimization - Steepest descent method, Conjugate Gradient method, Powell's method, Hooke-Jeeves method.	8
V	Kuhn-Tucker conditions. Quadratic programming - Dynamic programming - Examples -solution of dynamic programming problems using calculus method.	8
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE161A	POWER CONVERTER CIRCUITS	PCC	3	0	0	3	2022

i) COURSE OBJECTIVES

This course aims to impart the knowledge of power semiconductor devices and their applications and it also aims to analyse and design various power electronic converters.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Identify the different types of static switches used in power electronic circuits.	Understand
CO 2	Model the performance parameters of uncontrolled and controlled rectifiers.	Apply
CO 3	Analyse the performance of various DC-DC Converters.	Analyse
CO 4	Make use of various modulation techniques to meet the performance specifications of Inverters	Apply

iii) SYLLABUS

Power electronic switches-Switching constraints- Characteristics-Losses; Switch model; Uncontrolled Rectifier; Single Phase- Three Phase- Filters- Line Current Distortion-Total Harmonic Distortion- Displacement Power Factor- Power Factor.

Controlled Rectifiers: single phase- Three phase- Semi-converter- Inversion mode of operation.

DC –DC converter-Buck Converter- Boost converter- Buck- Boost converter- Cuk Converter.

Switched Mode Power Converter- Isolation & Protection- Flyback -Forward- Push Pull converters; Half Bridge converter; Full Bridge converter.

Voltage Source Inverters- Single Phase- Three Phase; PWM Techniques; Harmonic Elimination; Current Source Inverter; Multilevel Inverter.

iv) REFERENCES

1) Rashid M. H., *Power Electronics – Circuits, Devices and Applications*, Prentice Hall of India, New Delhi, 4th Edition, 2014.
2) Ned Mohan, Tore M. Undeland and William P. Robbins, *Power Electronics: Converters, Applications, and Design*, Wiley India, 3rd Edition, 2018.
3) Umanand L., *Power Electronics: Essentials and Applications*, Wiley, 2009.
4) Singh M. D. and Khanchandani K. B., *Power Electronics*, Tata McGraw Hills, Publishing Company Limited ,2006.
5) Daniel W. Hart, *Introduction to Power Electronics*, Prentice Hall, 1997.

6) William Shepherd and Li Zhang, *Power Converter Circuits*, Marcel Dekker, 2004.
7) Dubey G. K., Doradla S. R. and Sinha R. M. K., *Thyristorised Power Controllers*, New Age International Publications, 2005.
8) Joseph Vithayathil, *Power Electronics: Principles and Applications*, McGraw-Hill, 2010.

v) COURSE PLAN

Module	Contents	No. of hours
I	**Power Electronic Elements:** The ideal switch, Characteristics of ideal switches, two-quadrant and four-quadrant switches-Switching constraints in power electronic circuits. Losses in practical switches: Model of MOSFET for evaluating conduction and switching losses. Uncontrolled rectifiers: Single phase - Analysis with R load Analysis with capacitive filter.	9
II	**Controlled Rectifiers:** Single phase & Three phase fully controlled and semi controlled- Performance Analysis with RL, RLE loads Fourier Analysis of repetitive waveforms, Line current Distortion, Total Harmonic Distortion, Displacement Power Factor, Power Factor. Line voltage distortion, Effect of source impedance, Inversion mode of operation.	9
III	**DC-DC Converters:** Steady state analysis and design of DC to DC converters. Buck, Boost, Buck Boost, cuk -Control methods of DC to DC converters- duty ratio control, Voltage conversion ratios of different topologies, Current ripple and voltage ripple calculations. Switched Mode Power Supply - Requirements of isolation and protection.	9
IV	**Isolated DC-DC converter topologies:** Fly-back and forward converters, Push-pull converter, Half bridge and full bridge topologies, Steady state analysis - Voltage conversion ratios. AC voltage Regulator: Single phase AC regulator with R ,RL load, RMS output voltage and Power Factor, Sequence control.	9
V	**Inverters:** Performance analysis of single-phase voltage source inverter, Three Phase Inverters - PWM Techniques - sinusoidal pulse modulation, unipolar and bipolar PWM scheme. Space vector pulse width modulation Current source inverters, Concept of multi-level inverters.	9
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE161B	MODELLING OF ELECTRICAL MACHINES	PCC	3	0	0	3	2022

i) COURSE OBJECTIVES:

This course is introduced to analyse the electrical machine behaviour based on the voltage and torque equations of the machine and its transformation using different methods. This course also provides the concept of generalized machine theory and its application in DC machines, synchronous machine, single phase and three phase Induction motor. This course also imparts knowledge about the analysis of transient and steady state behaviour of rotating electrical machines.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Develop the basic two pole model representation of electrical machines	Apply
CO 2	Develop the linear transformation equations of rotating electrical machines incorporating the concept of power invariance.	Apply
CO 3	Analyse the steady state behaviour of different types of rotating electrical machines by applying linear transformations.	Analyse
CO 4	Analyse the transient behaviour of different types of rotating electrical machines by applying linear transformations.	Analyse

iii) SYLLABUS

Unified approach to the analysis of electrical machine performance - basic two pole model of rotating machines- per unit system

Primitive machine - transformer and rotational voltages in the armature voltage and torque equations resistance, inductance and torque matrix.

Transformations - passive linear transformation in machines- Park's transformation-invariance of power.

DC Machines- Application of generalized theory to separately excited, shunt and series machines- Steady state and transient analysis, transfer functions.

Synchronous Machines- reactance and time constants-Primitive machine model of synchronous machine - Balanced steady state analysis-power angle curves-Transient analysis.

Induction Machines- Primitive machine representation- Steady State Operation-Equivalent circuit. Double cage rotor representation- Single phase induction motor- Voltage and Torque equations.

iv) REFERENCES

1) P. S. Bhimbra, *Generalized Theory of Electrical Machines*, 6th Edition Khanna Publishers, Delhi 2017.
2) Charles V. Johnes, *Unified Theory of Electrical Machines*. New York, Plenum Press,1985.
3) Bernad Adkins, Ronald G Harley, *General theory of ac machines*. London, Springer Publications,2013.
4) Paul C. Krause, Oleg Wasynczuk, Scott D. Sudhoff, *Analysis of Electrical Machines and Drive Systems*, John Wiley & Sons,2013.
5) Charles Concordia, *Synchronous Machines- Theory and Performance,* John Wiley and Sons Incorporate, Newyork.1988.
6) Alexander S Langsdorf, Theory of Alternating Current Machinery, Tata McGraw Hill, 2nd revised Edition, 2001.
7) Langsdorf M. N., *Theory of Alternating Current Machinery*, Tata McGraw Hill, 2001.
8) M. G. Say, *Introduction to Unified Theory of Electrical Machine,* Pitman Publishing,1978.
9) NPTEL : http://nptel.ac.in/courses/108106023/

v) COURSE PLAN

Module	Contents	No. of hours
I	**Unified approach to the analysis of electrical machine performance -** Essentials of rotating electrical machines - conventions - Basic two pole model of rotating machines- Primitive machine - DC compound and shunt machines with interpoles, single phase series machine, three phase induction machine- per unit system - Transformer and Rotational voltages in the armature- Voltage and Torque equations resistance, inductance and torque matrix.	**8**
II	**Transformations -** Passive linear transformation in machines, power invariance, Transformation from a displaced brush axis-Transformation from three phase to two phase and from rotating axes to stationary axes-Physical concept of Park's transformation- Restrictions of the Generalized theory of machines, Numerical Problems.	**9**
III	**DC Machines:** Application of generalized theory to separately excited, shunt, series and compound machines. Expression for Rotational Mutual Inductance-Steady state and transient analysis, transfer functions of separately excited DC generator on no load and loaded conditions. Sudden short circuit of separately excited generator, Numerical Problems	**9**
IV	**Synchronous Machines:** Synchronous machine Parameters-Expression for armature self-Inductance, armature mutual Inductance, Synchronous reactance and time constants-Primitive machine model of synchronous machine without damper windings. Phasor diagram of Synchronous motor and Synchronous generator-balanced steady state analysis-Active	**10**

	and reactive power. power angle curves for Salient pole and Cylindrical rotor machine, Steady state stability limit Curve for different excitations, Numerical Problems.	
V	**Induction Machines:** Primitive machine representation Transformation-Torque equation, Steady state Analysis-Equivalent circuit, Torque slip characteristics -Double cage rotor representation- Equivalent circuit. Comparison between single cage and double cage Induction motor. Numerical Problems. **Single phase induction motor**- Double Revolving Field Theory-equivalent circuit- Voltage and Torque equations- Cross field theory -Steady state Analysis, Comparison between single phase and poly phase Induction motor.	**9**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22MC061A	RESEARCH METHODOLOGY & IPR	RM	2	0	0	2	2022

i) COURSE OBJECTIVES

This course is intended to prepare the M. Tech students to carry out their dissertation/ research project work effectively, with a research bias. The student will be able to formulate a viable research problem, do a critical analysis of publications in the area of research, and identify a research method suitable for the work. The student will achieve the capability to write a technical paper based on his/her dissertation/ research project.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

#	Description	Level
CO1	Demonstrate core ethical principles in all stages of a research activity	Understand
CO2	Formulate a research problem, and prepare appropriate research design.	Apply
CO3	Identify the appropriate method for data collection, and analyse the collected data to form meaningful conclusions.	Analyse
CO4	Apply the IPR and Patent law in the creation of improved products, fostering economic growth and social benefits.	Apply
CO5	Apply the competence in documentation and reporting in writing technical papers for publication.	Apply

iii) SYLLABUS

Introduction to Research Methodology- motivation for research, types of research, ethical issues. Identifying a research area and collecting related literature. Research problem- scope-objectives, literature review, identifying research gaps, and formulate the research problem. Research design and methods, data collection and analysis. Copy right – royalty - IPR and patent law. Process of patenting and development, Procedure for grant of patents. Copy left- open access, citation, plagiarism, iImpact factor. Writing a technical paper.

iv) REFERENCES

i) Stuart Melville and Wayne Goddard, *Research methodology: an introduction for science & engineering students.*
ii) Ranjit Kumar, 2nd Edition, *Research Methodology: A Step by Step Guide for beginners*.
iii) Ramappa T., *Intellectual Property Rights Under WTO*, S. Chand, 2008.
iv) Robert P. Merges, Peter S. Menell, Mark A. Lemley, *Intellectual Property in New Technological Age*, 2016.
v) Mayall, *Industrial Design*, McGraw Hill, 1992. Niebel, “Product Design”, McGraw Hill, 1974.

v) COURSE PLAN:

Module	Contents	Hours
I	Introduction to Research Methodology: Motivation towards research, Types of research. Professional ethics in research: Ethical issues, ethical committees. Identification of major conferences and important journals in a chosen area of interest. Collection of at least 10 published papers on a research problem in the chosen area.	**6**
II	Defining and formulating the research problem: Literature Survey, Analysing the collected papers to understand how the authors haveidentified the research gaps, arrived at their objectives, and formulated their research problem. Understanding how their research work is different from the previous works in the chosen area.	**6**
III	Research design and methods: Analyzing the collected papers to understand how the authors have formulated the research methods, both analytical methods and experimental methods. Data Collection and analysis: Analyzing the collected papers to understand the methods of data collection, data processing, analysis strategies, and tools used for analyzing the data.	**6**
IV	Copy right - royalty - Intellectual property rights and patent law – Process of Patenting and Development, Procedure for grant of patents. Reproduction of published material: Copy left- Open access, Citation and acknowledgement. Plagiarism, Impact factor.	**6**
V	Technical writing - Structure and components of a typical technical paper, abstract and conclusion, illustrations and tables, bibliography, referencing and footnotes. Writing a technical paper – based on the identified research problem, and using the collected papers, Literature survey, Problem formulation, and Research design, and a hypothetical result.	**6**
Total hours		**30**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE169A	POWER ELECTRONICS LAB	LBC	0	0	2	1	2022

i) COURSE OBJECTIVES

The main objective of the course is to expose the students to hands on triggering circuit, DC-DC converter circuits, Inverters, PWM generation and computer simulation of various Converter circuits.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Examine various power converter circuits using simulation techniques	Analyse
CO 2	Analyse the performance of gate drive circuit and PWM generator.	Analyse
CO 3	Experiment the performance of power converters	Apply

iii) LIST OF EXPERIMENTS

1. DC-DC Choppers using self-commutating Devices.
   a) Buck Converter
   b) Boost converter
2. AC-AC voltage regulators
   a) Lamp load
   b) Motor load
3. Practical converter design considerations - gate and base drive circuits
4. Generation of sine-PWM using analog circuits
5. Push pull inverter.
6. Computer simulations of Single-phase uncontrolled converter, Semi converters and Full converters
   a) R load
   b) RL load
   c) RLE load
7. Computer simulations of three phase uncontrolled converter, Semi converters and Full converters
   a) R load
   b) RL load
   c) RLE load
8. Computer simulation of DC-DC regulator

iv) REFERENCES

1) Rashid M H, *Power Electronics – Circuits, Devices and Applications*, Prentice Hall of India, New Delhi, 4th Edition, 2014.
2) Ned Mohan, Tore M. Undeland, William P. Robbins, *Power Electronics: Converters, Applications, and Design*, 3rd Edition ,2002.

v) COURSE PLAN

Expt. No.	Contents	No.of hours
1	DC-DC Choppers using self-commutating Devices. a) Buck Converter b) Boost converter a) Design and set-up Buck and Boost DC-DC converter b) Plot the waveforms of triggering circuit and power circuit	4
2	AC-AC voltage regulators a) Lamp load b) Motor load a) Design and set-up an AC voltage controller using lamp load & motor load b) Plot the different waveforms by varying the triggering angle	3
3	Practical converter design considerations - gate and base drive circuits a) Design, set-up and observe the waveforms of gate trigger circuit for Power MOSFET b) Design, set-up and observe the waveforms of gate trigger circuit for Power BJT	4
4	Generation of sine-PWM using analog circuits a) Design and set-up Sine triangle pulse width modulation circuits using OPAMP b) Plot the waveforms and observe the change in output for different modulation index	4
5	Push pull inverter. a) Design and set-up push pull inverter circuit using TL 494 b) Plot the trigger pulse and output waveforms	3
6	MATLAB simulations of Single-phase uncontrolled converter, Semi converters and Full converters a) R load b) RL load c) RLE (motor) load. a) Simulate single phase rectifier circuits in MATLAB b) Observe the waveforms and performance with R, RL, & RLE load	4
7	MATLAB simulations of three phase uncontrolled converter, Semi converters and Full converters a) R load b) RL load c) RLE (motor) load a) Simulate three phase rectifier circuits in MATLAB b) Observe the waveforms and performance with R, RL & RLE load	4
8	MATLAB simulation of DC-DC regulator a) Simulate Buck or Boost DC-DC converters b) Observe the waveforms and performance for various duty cycle	4
	Total Hours	**30**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162A	ADVANCED SIGNAL PROCESSING	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

This course is designed with the analysis, study, interpretation and manipulation of signals. The signals may be audio, image, video ECG EEG signals captured by communication receivers, seismic signals. Signal processing techniques are finding important applications in wide areas of technology ranging from wired and wireless communication to multimedia processing to medical diagnosis to earth quake prediction.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Construct signals in the discrete domain for various applications	Apply
CO 2	Apply discrete Fourier transform (DFT) and Fast Fourier transform (FFT) in a sequence.	Apply
CO 3	Develop filters to meet specific requirements for various applications.	Apply
CO 4	Analyse the time-frequency response of signals using short time Fourier transform	Analyse
CO 5	Demonstrate the applications of multi-rate signal processing and different DSP processors.	Understand

iii) SYLLABUS

Discrete time signals and Systems: Review of DTS, LTI systems, linear convolution and its properties, Z transform and Inverse Z- transform

Discrete Fourier Transform and Fast Fourier Transform: Discrete time sequences, Discrete Fourier Transform, properties, linear convolution using DFT, Fast Fourier Transform.

Filter Design Techniques: Design of Discrete-Time IIR filters from Continuous-Time filters, bilinear transformation technique, Impulse invariance method. FIR filter design, Fourier series method.

Finite Word Length Effects and Time frequency analysis, Effects of coefficient on Quantization, Discrete Fourier Transform Computations, Time frequency distribution, Short time Fourier Transform, Wigner distribution, Wavelet transform.

Multi rate signal processing: Decimation by a factor D, Multi stage implementation of sampling rate conversion, Filter design and efficient implementation for sampling rate conversion.

Application of Multi rate signal processing & Processors: Phase shifters – Interfacing of digital systems with different sampling rates - Oversampled A/D and D/A converter, TMS C240 processor and ADSP 2181 processor.

iv) REFERENCES:

1) Glenn Zelniker, Fred J. Taylor, Advanced *Digital Signal Processing – Theory and Applications,* CRC Press, 1993.
2) A.V. Oppenheim and Schafer, *Discrete Time Signal Processing*, Prentice Hall, 2nd Edition, 1998.
3) John G. Proakis and D.G. Manolakis, *Digital Signal Processing: Principles, Algorithms and Applications*, Prentice Hall International.Inc, 4th Edition, 2012.
4) Emmanuel C. Ifeacher, Barrie. W. Jervis, *DSP – A Practical Approach*, 2nd Edition, Pearson Education.
5) Lawrence R.Rabiner and Bernard Gold, *Theory and Application of Digital Signal Processing,* 2nd Edition, 2015.
6) Douglas F. Elliott, *Handbook of Digital Signal Processing- Engineering Application*, Academic Press, 2nd Edition, 2013.
7) Leon Cohen, *Time Frequency Analysis*, Prentice Hall, 1995.
8) P. P. Vaidyanathan, *Multirate systems and Filter Banks*, Prentice Hall, 1993.
9) Avatar Singh and Srinivasan S., *Digital Signal Processing: Implementation using DSP Microprocessors with Examples from TMS 320C54XX*', Thompson Brooks/Cole, 2004.

v) COURSE PLAN

Module	Contents	No. of hours
I	**Discrete time signals & Systems:** Review of DTS, stability & causality, LTI systems, linear convolution and its properties. Z transform-properties-system characterization in Z-domain, Inverse Z- transform **Discrete Fourier Transform:** Representation of Periodic Sequences: Discrete Fourier Transform (DFT), properties, linear convolution using DFT, Efficient computation of DFT.	10
II	**Fast Fourier Transform & IIR Filter Design Techniques:**, Fast Fourier Transform (FFT), Decimation in time and frequency algorithm, Classification of filter design, Design of Discrete-Time IIR filters from Continuous-Time filters, Block diagram representation of FIR & IIR filters, Bilinear transformation technique, Impulse invariance method.	9
III	**FIR Filter Design Techniques & Finite Word Length Effects:** FIR filters design, Fourier series method, Window function technique, A Comparison of IIR and FIR Digital Filters, Effects of coefficient on Quantization, Quantization in Sampling, Discrete Fourier Transform Computations.	8

IV	**Time frequency analysis & Multi rate signal processing:** the need for time frequency analysis, Time frequency distribution, Short time Fourier Transform, Wigner distribution, An introduction to multi component signal analysis- Wavelet transform, Mathematical description of sampling rate conversion - Decimation by a factor D, Interpolation by a factor I, Sampling rate conversion by a rational factor I/D	**9**
V	**Application of Multi rate signal processing & Processors:** Multi stage implementation of sampling rate conversion, Filter design and efficient implementation for sampling rate conversion- direct form FIR structures, Polyphase filter structures, Phase shifters – Interfacing of digital systems with different sampling rates - Sub band coding- Oversampled A/D and D/A converter, Commercial DSP devices, TMS C240 processor and ADSP 2181 processor, Architecture, Addressing modes.	**9**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162B	RENEWABLE ENERGY TECHNOLOGIES	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

This course is to expose the students to the fundamental concepts of emerging renewable energy sources available, its working principle and advantages.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Develop solar energy systems for various applications.	Apply
CO 2	Explain the methods of energy generation from ocean waves and tides.	Understand
CO 3	Apply the concepts of wind energy in power generation and conversion systems	Apply
CO 4	Demonstrate the operation of emerging energy generation schemes	Understand

iii) SYLLABUS

Direct solar energy-Solar radiation data- measurement; Solar thermal systems- Solar thermal collectors- solar thermal electric systems; estimation of average solar radiation.

Energy from oceans- Wave energy generation-Wave energy conversion devices; Tidal energy, tidal power generation systems, Ocean thermal energy conversion.

Wind energy- Design of windmills – site selection considerations – Types of wind machines; Wind energy conversion systems- classification.

Small hydro power stations- Turbines and generators for SHP; Biomass and biofuels – Biogas generation: types of biogas plants, Energy from waste; Chemical energy generation: fuel cell -types; Batteries.

Geothermal energy-classification of geothermal resources- operational and environmental problems; Power from satellite stations; Hydrogen energy; Nuclear Fusion energy.

iv) REFERENCES

1) Solanki C. S., *Solar Photovoltaic: Fundamentals Technologies and Applications*, Prentice-Hall of India Pvt. Limited, 3rd Edition ,2015
2) Joshua Earnest and Tore Wizelius, *Wind Power Plants and Project Development*, Prentice-Hall of India Learning, 2nd Edition, 2015.
3) Rai. G.D., *Solar Energy Utilization*, Khanna Publishers, 5th Edition, 2014.
4) Rai. G.D., *Non-conventional Energy Sources*, Khanna publishers,6th Edition, 2017.

5) Kothari, *Renewable Energy Sources and Emerging Technologies*, Prentice-Hall of India, Eastern Economy Edition, 2012.
6) Earnest J. and Wizelius T., *Wind Power Plants and Project Development*, PHI Learning, 2011.
7) Khan B. H., *Non-Conventional Energy Resources*, Tata McGraw Hill, 2009.
8) Sawhney G. S., *Non-Conventional Energy Resources*, Prentice-Hall of India Learning, 2012.

v) COURSE PLAN

Module	Contents	No. of hours
I	**Direct solar energy**-The sun as a perennial source of energy. direct solar energy utilization, Solar radiation measurements, solar radiation data, estimation of average solar radiation, Solar Thermal electric systems; solar photovoltaic power generation. Applications of solar energy – water heating systems, space heating and cooling of buildings, solar ponds and solar green houses.	9
II	**Energy from oceans**-Wave energy generation - potential and kinetic energy from waves; wave energy conversion devices. Tidal energy - basic principles, tidal power generation systems, Ocean thermal energy conversion (OTEC), methods of ocean thermal electric power generation - Open Cycle, Closed Cycle and Hybrid Cycle.	9
III	**Wind energy** - basic principles of wind energy conversion; design of windmills; wind data and energy estimation. Site selection considerations. Types of wind machines-Horizontal axis and Vertical axis machines. Dynamics of Turbine blades.	9
IV	**Classification of small hydro power (SHP) stations**; Turbines and generators for SHP; advantages and limitations. Biomass and bio -fuels; energy plantation; biogas generation; types of biogas plants- floating type and fixed dome type. Applications of biogas; energy from wastes.	9
V	**Geothermal energy**- Origin and nature of geothermal energy, classification of geothermal resources, schematic of geothermal power plants, operational and environmental problems; Power from satellite stations, Hydrogen energy –production-storage-transportation –utilization, nuclear fusion energy, cold fusion.	9
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162C	FLEXIBLE AC TRANSMISSION SYSTEMS	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

This course imparts knowledge on advances in Power electronics Industry that led to rapid development of Power Electronics controllers for fast real and reactive power control. The aim of this course is to familiarise the operation and analysis of different FACTS devices. The insight of introducing this course is to enable students to design a power system with proper control for real and reactive power using FACTS devices.

ii) COURSE OUTCOMES

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

CO 1	Explain the basic concepts and benefits of FACTS	Understand
CO 2	Apply the concepts of power flow control in AC power transmission systems.	Apply
CO 3	Explain the various static series and shunt reactive power compensated systems.	Understand
CO 4	Apply the concept of shunt, series and combined series shunt compensators in switching converters.	Apply

iii) SYLLABUS

Power flow control – Voltage regulation and Reactive power flow control-Transmission line compensation - Phase angle control.
Reactive power compensation – shunt and series compensation principles. Converters for static compensation.
Static shunt Compensator - Variable impedance type VAR Generators -TCR, TSR, TSC, FC-TCR.
Static Series compensator - Variable impedance type series compensators – GCSC, TCSC, TSSC.
Static Voltage and Phase Angle Regulators - TCVR &TCPAR -Switching converter - Applications
Switching converter type shunt Compensators - SVC and STATCOM – Regulation – Comparison between SVC and STATCOM. Applications of Switching converter type Series Compensators - SSSC.
Combined series-shunt compensator – Unified Power Flow Controller - principle of P and Q control - Applications. Interline Power Flow Controller. Simulation of FACTS controllers.

iv) REFERENCES

1) N. G. Hingorani and L. Gyugyi, *Understanding FACTS*, IEEE Press, 2000.

2) T. J. E. Miller, *Reactive Power Control in Power Systems*, John Wiley, 1982.
3) K. R. Padiyar, *FACTS Controllers in Power Transmission and Distribution*, New Age International Publishers, 2007.
4) J. Arriliga and N. R. Watson, *Computer modeling of Electrical Power Systems*, Wiley, 2001.
5) Y.H. Song and A.T. Johns, *Flexible ac Transmission Systems (FACTS)*, IEEE Press, 1999.
6) Ned Mohan et. al, *Power Electronics*, John Wiley and Sons, 1995.

v) COURSE PLAN

Module	Contents	No. of hours
I	**Power flow in Power Systems** – Steady-state and dynamic problems in AC systems – Voltage regulation and reactive power flow control in Power Systems – control of dynamic power unbalances in Power System. **Power flow control** - Constraints of maximum transmission line Loading. **Benefits of FACTS** - Transmission line compensation Uncompensated line -shunt compensation - Series compensation - Phase angle control.	9
II	**Reactive power compensation** – shunt and series compensation principles – reactive compensation at transmission and distribution level – Static versus passive VAr Compensators. **Converters for Static Compensation** - Three Phase Converters and Standard Modulation Strategies. GTO Inverters. Multi-level inverters and their modulation.	9
III	**Static shunt Compensator** - Objectives of shunt compensations, Methods of controllable VAR generation - Variable impedance type VAR Generators -TCR, TSR, TSC, FC-TCR Principle of operation, configuration, and control. **Static Series compensator** - Objectives of series compensations, Variable impedance type series compensators – GCSC, TCSC, TSSC - Principle of operation, configuration, and control.	9
IV	**Static Voltage and Phase Angle Regulators** TCVR &TCPAR - Objectives of Voltage and Phase angle regulators. Thyristor controlled Voltage and Phase Angle Regulators - Switching converter type Voltage and Phase Angle Regulators- Applications. **Switching converter type shunt Compensators** - Principle of operation, configuration and control, SVC and STATCOM - Regulation slope. Comparison between SVC and STATCOM – Applications - Switching converter type Series Compensators SSSC - Principle of operation, configuration, and control.	10

V	**Combined series-shunt compensator** – Unified Power Flow Controller: Circuit Arrangement, Operation, and control of UPFC- Basic principle of P and Q control - independent real and reactive power flow control- Applications. Introduction to interline power flow controller. Modeling and simulation of FACTS controllers	**8**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162D	MICROCONTROLLER APPLICATIONS IN POWER ELECTRONICS	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

This course develops the students to know the architecture and operation of 8051 microcontrollers. It will also help to understand how embedded devices can be used in the field of power electronics. The course will make the students understand the utility of 8051 microcontrollers for better controlling of Electrical circuits. The course will impart the knowledge to students about the measurement of electrical and non-electrical quantities using processors.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Apply microcontroller for serial port communication/interfacing using timers/counters of 8051.	Apply
CO 2	Interpret electrical quantities by signal conditioning using processors	Understand
CO 3	Utilize processors to control non-electrical quantities.	Apply
CO 4	Apply microcontrollers in various control schemes of electrical circuits	Apply

iii) SYLLABUS

Evolution of microcontrollers: 051 architecture- Assembly language, Interrupts & Timers/Counters. Internal RAM & ROM, ADC & DAC interfacing with the controller.

Microprocessor based applications: Signal conditioning using comparators, Measurement of voltage, current, speed, power and power factor using microprocessors.

Microprocessor based control: Measurement of non-electrical quantities like Strain, Temperature, Speed and Torque. Implementation of P, PI and PID controllers using microprocessors

Applications of MCS-51 Microcontrollers: Square Wave Generation- Rectangular Waves-Pulse Generation- Frequency Counter, Digital pulse width modulation techniques.

Microcontroller Based Firing Scheme for Converters: 3-phase AC choppers, Inverters, control of power electronic converters for power supplies and electric motor drives: Stepper motor, DC motor & AC motor control.

iv) REFERENCES

1) Kenheth J. Hintz and Daniel Tabak, *Microcontrollers: Architecture, Implementation and Programming*', McGraw Hill, USA, 1992

2) John B. Peatman, *Design with Microcontrollers*, McGraw-Hill International Ltd, 1997
3) *8-bit Embedded Controllers*, Intel Corporation, 1990
4) John B. Peatman, *Design with PIC Microcontrollers*, Pearson Education Inc., India, 2005
5) Douglas V. Hall, *Microprocessors and Interfacing: Programming and Hardware*, Tata McGraw-Hill, 11th Edition, 2003.
6) Ajay V Deshmukh, *Micro controllers-Theory and Applications*, McGraw Hills, 2nd Edition, 2005.

v) COURSE PLAN

Module	Contents	No. of hours
I	**Evolution of microcontrollers:** Comparison between microprocessor and microcontroller. 8051 architecture- CPU structure-register file, special function registers, registers and pin description. Assembly language, addressing modes-instruction set. **Interrupts & Timers/Counters:** Interrupt structure – timers/counters. Serial data input/output. Internal RAM & ROM, interfacing with external memory, ADC & DAC interfacing with the controller,PWM signal generation using timer/counter.	9
II	**Microprocessor based applications:** Importance of measurement and sensing in closed loop control. Signal conditioning using comparators, Clippers, Clampers, Precision Rectifier and Zero crossing Detector. Measurement of voltage, current, speed, power and power factor using microprocessors.	9
III	**Microprocessor based control:** Measurement of non-electrical quantities like Strain, Temperature, Speed and Torque. Per-unit representation of variables in digital domain, data representation in fixed point and floating point form, round-off errors- Implementation of P, PI and PID controllers using microprocessors.	9
IV	**Applications of MCS-51 Microcontrollers**: Square Wave Generation-Rectangular Waves- Pulse Generation- Pulse Width Modulation-Staircase Ramp Generation- Sine Wave Generation. Pulse Width Measurement- Frequency Counter. Digital pulse width modulation techniques and its comparison with the analog type.	9
V	**Microcontroller Based Firing Scheme For Converters:** Firing schemes for single phase and three phase rectifiers-3-phase AC choppers, Firing at variable frequency environments, Firing scheme for DC choppers, voltage and current commutation. Inverters, types of pulse width modulation techniques, their implementation. Using microcontrollers, application of the firing schemes to the control of DC drive, induction motors, synchronous motors and other special machines. Typical applications in the control of power electronic converters for power supplies and electric motor drives: Stepper motor control, DC motor control, AC motor control.	9
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162E	SOFT COMPUTING TECHNIQUES	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

Goal of this course is to provide students the concepts of different soft computing techniques. It gives an insight into the different types of Artificial Neural Network architectures, the learning processes and algorithms, the properties and operations of fuzzy logic, the working of a fuzzy logic system, the operators of Genetic Algorithms and finally some of the hybrid systems. It also gives an idea on the application of soft computing techniques on different systems. It also aims to provide a basic knowledge on using the different soft computing toolboxes in Computer.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Apply fuzzy logic in various physical systems.	Apply
CO 2	Compare the different Artificial Neural Network Architectures.	Understand
CO 3	Apply Genetic Algorithm to attain an optimal solution to a given problem.	Apply
CO 4	Explain various hybrid techniques in soft computing	Understand

iii) SYLLABUS

Basic Introduction – Difference between soft computing and hard computing, artificial intelligence.
Artificial Neural Networks – Biological foundations, ANN models, architecture, Learning, Supervised and unsupervised learning, Back propagation network, Adaptive Resonance Theory, Applications, Case studies.
Fuzzy logic – Fuzzy set properties and operations; membership functions, Fuzzy logic systems, Applications.
Genetic Algorithm – basic concepts, operators, steps.
Hybrid Systems – Adaptive Neuro-fuzzy Inference System, Genetic algorithm based back propagation networks, fuzzy back propagation networks.

iv) REFERENCES

1) Timothy J. Ross, *Fuzzy logic with Engineering Applications*, Wiley Publications, 3rd Edition, 2010.
2) Sivanandan S. N., Deepa S. N., *Principles of Soft Computing*, Wiley India, 2007.
3) Zurada J. M., *Introduction to Artificial Neural Systems*, Jaico Publishers, 2003.
4) Rajasekharan S., Vijayalakshmi Pai G. A., *Neural Network, Fuzzy Logic and Genetic Algorithms Synthesis and Applications*, Prentice Hall India, 2003.
5) Ronald R. Yager and Dimitar P. Filev, *Essentials of Fuzzy Modelling & Control*, John Wiley & Sons, Inc, 2002.
6) Bart Kosko, *Neural Network and Fuzzy Systems*, Prentice Hall of India, 2002

7) Hassoun Mohammed H., *Fundamentals of Artificial Neural Networks*, Prentice Hall of India, 2002.
8) Simon Haykin, *Neural Networks a Comprehensive foundation*, Pearson Education, 1999.
9) Jang J. S. R., Sun C. T., Mizutani E., *Neuro-Fuzzy and Soft Computing*, Prentice Hall, 1997.
10) Suran Goonatilake & Sukhdev Khebbal (Eds.), *Intelligent Hybrid Systems*, John Wiley, 1995.
11) Driankov D., Hellendoorn H., Reinfrank M, *An Introduction to Fuzzy Control*, Narosa Publications, 1993.
12) Goldberg D. E., *Genetic Algorithms in Search Optimisation and Machine Learning*, Pearson Education, 1989.

v) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction**: Conventional and Modern Control System, Soft and Hard Computing, Artificial Intelligence. **Artificial Neural Networks**: Biological foundations – ANN models - Characteristics of ANN - Types of activation function - McCulloch-Pitts neuron model. **Neural network architecture and learning:** Single layer, multilayer, recurrent network architectures. Learning process - Supervised and unsupervised learning, Error correction learning - Hebbian learning – Boltzmann learning - competitive learning.	9
II	Perceptrons, Adaptive Linear Neuron, Multiple Adaptive Linear Neuron, Back propagation network and its architecture, Derivation of the back-propagation algorithm, Radial basis function network. Applications of Neural Networks, Neural Network Toolbox in MATLAB.	9
III	**Fuzzy sets and Fuzzy logic**: Introduction, Fuzzy sets versus crisp sets, Membership functions, properties, operations on fuzzy sets. Block diagram - Fuzzification, rule base, inference engine and defuzzification methods.	9
IV	**Fuzzy logic controller**: Fuzzy models - Mamdani Fuzzy Models, Sugeno Fuzzy Models, fuzzy controllers, fuzzy pattern recognition, fuzzy image processing. Engineering Applications - inverted pendulum, home heating system. Fuzzy logic toolbox in MATLAB.	9
V	**Genetic Algorithm**: Introduction - basic concepts of Genetic Algorithm, encoding, fitness function, reproduction, cross over, mutation operator, bit-wise operators, generational cycle-Application in physical systems. **Hybrid Techniques**: Adaptive Neuro-fuzzy Inference System (ANFIS), Genetic algorithm based back propagation networks, fuzzy back propagation networks.	9
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162F	PWM SCHEMES FOR POWER CONVERTERS	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

Goal of this course is to impart knowledge about fundamentals concepts of PWM schemes and control techniques used for power converters. The course deals with detailed study of different inverter topologies and analysis of modulation techniques like sine PWM and SVPWM. Also the course gives an overview of different multilevel inverter topologies.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Analyse steady state behavior of various power converters using simple switch elements	Analyse
CO 2	Analyse single phase and three phase inverters using fourier techniques	Analyse
CO 3	Compare the performance of various modulation strategies	Understand
CO 4	Choose suitable modulation strategies for Multilevel Converters.	Apply

iii) SYLLABUS

Single Single-Pole-Double-Throw and Single-Pole-Multi-Throw representation of power converters- Topologies of Inverters - Representation using ideal switches- square wave operation.

Fourier Analysis of single phase and three phase Inverters-Basic modulation techniques - implementation of unipolar and bipolar modulation.

Three phase Voltage Source Inverters -Sine-Triangle PWM of three phase VSI-Space Vector PWM-Comparison of SPWM and SVPWM. Harmonic distortion and losses in PWM-Over modulation-Current controlled PWM.

Multilevel Converters-Topologies-Principle of operation-Modulation Strategy.

iv) REFERENCES

1) *Ned Mohan, Tore M. Undeland, William P. Robbins, Power Electronics Converters*
2) *Applications and Design, 3rd Edition, Wiley India Pvt Ltd, 2010.*
3) *Umanand L, Power Electronics- Essentials and Applications, Wiley, 2011.*
4) G.Holmes & T.A. Lipo, *Pulse width Modulation for Power Converters*, Principle and

practice, IEEE Press, 2003.

5) Daniel W Hart, *Power Electronics*, Tata McGraw Hill, 2011.
6) G.K. Dubey, et.al,*Thyristorised Power Controllers*, Wiley Eastern Edition,4th Edition.
7) M.P.Kazmierkowski ,*Control of Power Converters : Selected Problems*, Academic Press, 2003.
8) Joseph Vithayathil, *Power Electronics:* Principles and Applications, McGrawhill Edition, 2010.

v) COURSE PLAN

Module	Contents	No. of hours
I	Switched Mode Inverters: Relation between Pole voltages, Line voltages and Line-to-load neutral voltages in multi-phase two-level inverters. Analysis of Inverters - Single phase bridge type VSI -Output rms voltage, Fourier harmonics analysis, THD -Three Phase Voltage Source Inverter - Output rms voltage, Fourier harmonics analysis, THD	9
II	Modulation Techniques of Single Phase Inverters -Single pulse, Multiple Pulse and Sine-Triangle modulation, duty ratio - Implementation of unipolar and bipolar modulation- Selective Harmonic Elimination -linear modulation and over modulation	9
III	Three phase Voltage Source Inverters (VSI) -Sine- Triangle PWM Space Vector PWM – Conventional Sequence, Dwell time calculation-Optimum switching in space vector PWM, Space vector diagram. Comparison of Sine-Triangle PWM and Space Vector PWM –DC bus voltage utilization	9
IV	Zero vectors and importance of their placement in PWM – Harmonic Distortion- Harmonic Distortion factors for 3 phase inverters, Harmonic losses in PWM. Current controlled PWM VSI -Hysteresis Control - fixed band and variable band hysteresis.	9
V	Introduction to multi-level inverters –Neutral Point Clamped multi-level inverter, Flying Capacitor multi-level inverters, Cascaded Multilevel Inverter Topologies - Principle of operation.	9
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162G	DYNAMICS OF LINEAR SYSTEMS	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

The course will provide knowledge of linear system modelling, analysis and design so as to obtain the ability to apply the same to engineering problems in a global perspective. The students will be able to carry out controller design to achieve stability of systems. Also, it will provide knowledge to design observers and controllers for linear systems so as to be able to implement the methodology for practical control systems.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Analyze a given system and assess its performance	Analyse
CO 2	Design a suitable compensator to meet the required specifications	Design
CO 3	Design and tune PID controllers for a given system	Design
CO 4	Realize a linear system in state space domain and to evaluate controllability and observability	Apply
CO 5	Design a controller and observer for a given system and evaluate its performance	Design

iii) SYLLABUS

Design of feedback control systems- Review of compensator design using Root locus and Bode plots- PID controllers

State Space Analysis Design- Linear state variable feedback for SISO systems-

State Space Analysis Design formulae for feedback gain-Transfer function approach-controllable and uncontrollable modes - regulator problems,

Observers - Asymptotic observers for state measurement-implementation of the observer-full order and reduced order observers combined observer–controller

MIMO systems - Introduction-controllability-observability- different companion forms for MIMO systems.

iv) REFERENCES

1) Richard C. Dorf & Robert H. Bishop, *Modern Control Systems,* Pearson Education, Limited, 12th Edition, 2013

2) Gene K. Franklin & J. David Powell, *Feedback Control of Dynamic Systems*, Pearson Education, 8th Edition, 2018
3) M. Gopal, *Control Systems-Principles and Design*, Tata McGraw-Hill, 4th Edition, 2012.
4) Nagrath, J. J. Gopal, M – *Control System Engineering*, New Age International Pvt Ltd, 6th Edition, 2018
5) Thomas Kailath, *Linear System*, Prentice Hall Inc., Eaglewood Cliffs, NJ, 1998
6) Harold Klee, Randal Allen, *Simulation of Dynamic Systems with MATLAB and Simulink*, CRC Press, 3rd Edition, 2018
7) C.T. Chen, *Linear System Theory and Design*, New York, Oxford university press, 4th Edition, 2014.

v) COURSE PLAN

Module	Contents	No. of hours
I	**Design of Controllers & Compensators:** Design of feedback control systems- Approaches to system design compensators– performance measures- cascade compensation networks phase lead and lag compensator design using both Root locus and Bode plots PID controllers-effect of proportional, integral and derivative gains on system performance- PID tuning-integral windup and solutions Matlab Simulation of a typical power converter control using PID	9
II	**State Space Analysis:** State Space Analysis and Design- Analysis of stabilization by pole cancellation- reachability and constructability - Stabilizability - controllability - observability-Analysis of stabilization by output feedback-Transfer function approach - state feedback and zeros of the transfer function.	9
III	**State Feedback Controllers:** Linear state variable feedback for SISO systems, -modal controllability formulae for feedback gain-Ackermann's formula feedback gains in terms of Eigen values - Mayne- Murdoch formula - non controllable realizations and stabilizability - controllable and uncontrollable modes - regulator problems Matlab Simulation of speed control of a DC/AC motor using Feedback controllers.	9
IV	**Observers:** Asymptotic observers for state measurement-open loop observer-closed loop observer-formulae for observer gain –implementation of the observer - full order and reduced order observers – separation principle - combined observer –controller.	9
V	**MIMO systems:** Design using polynomial equations - Direct analysis of the Diophantine equation. MIMO systems: Introduction, controllability, observability, different companion forms for MIMO systems.	9
	Total hours	**45**

ourse Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162H	APPLICATIONS OF POWER ELECTRONICS IN POWER SYSTEMS	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

This course aims to impart the knowledge to analyse the working and performance of power electronic circuits in FACTS and HVDC Transmission. It also familiarises the problems related to power quality and to determine the requirements of connecting a distributed generator to the utility system.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Explain the power flow control using FACTS devices in AC transmission systems.	Understand
CO 2	Compare the working of shunt and series compensators.	Understand
CO 3	Analyse converter circuits used in HVDC system.	Analyse
CO 4	Identify suitable methods to mitigate the power quality issues in distribution systems.	Apply
CO 5	Select control circuits for power devices for protection and Islanding in distributed generation.	Apply

iii) SYLLABUS

Flexible AC Transmission- Series and Shunt Compensation - Types of FACTS controllers. Operation and control of SVC, STATCOM, TCSC, SSSC
Power Quality problems in distribution systems-harmonics-Passive and active Filters - IEEE standards for power quality.
Need for HVDC, AC vs. DC: Comparative advantages. Converters and their characteristics. Control of the converters.
Distributed generation-Grid Interconnection - Modelling of converters in DG-Protection and control of grid converters.

iv) REFERENCES

1) Hingorani N. G, L. Gyugyi, Understanding Facts Concepts and Technology of Flexible Systems, Standard Publishers Distributors, 2001.
2) Roger C. Ducan, McGranaghan, Santose Beaty, Electrical Power Systems Quality, McGraw-Hill, New York, 2nd Edition, 2002.
3) K. R. Padiyar, HVDC Power Transmission Systems, Wiley eastern Ltd. 2008.
4) Lee Willis & Walter G. Scott, Distributed Power Generation, Planning & Evaluation, 1st Edition, CRC Press Taylor & Francis Group.

5) W. Kramer, S. Chakraborty, B. Kroposki, and H. Thomas, Advanced Power Electronic Interfaces for Distributed Energy Systems Part 1: Systems and Topologies, March 2008, Technical Report NREL/TP-581-42672

v) COURSE PLAN

Module	Contents	No. of hours
I	Concept of Flexible AC Transmission--Power flow in Uncompensated transmission line- Effect of series and shunt compensation at the mid-point of the line on power transfer- Benefits of FACTS controllers- Basic types of FACTS controllers. Static Shunt Compensators-Objectives of shunt compensations. Methods of VAR generation-Variable Impedance VAR-Switching Converter VAR-Hybrid VAR (Concept only)	9
II	Operation and control of SVC, STATCOM configuration and control, applications of SVC and STATCOM. Static Series Compensators-Objectives of Series Compensation. Principle of Operation, Analysis And Control, Applications of TCSC and SSSC. Principle of phase angle compensation –phase angle compensator	9
III	Need for HVDC, AC vs. DC: Comparative advantages. Components of HVDC-Types of Link. Converter Configuration-Analysis of Graetz circuit with and without overlap. Principle of DC link control-Converter control characteristics-constant minimum ignition angle control-constant current control-extinction angle control	9
IV	Power quality – Type of power quality disturbances-Sources and effects of power quality in distribution system. Harmonics–Harmonic Indices-Sources of Harmonics. Mitigation of Harmonics-Passive and Active Filters. Types of Active Filters- shunt, series and hybrid filters. IEEE standards on power quality	9
V	Distributed generations-Concept of DG- Grid Interconnection Standards, General Power electronic DG interconnection topologies for various sources and control. Control of DG inverters-Current control and DC voltage control for standalone and grid parallel operations. Local and Remote Techniques for Islanding Detection in Distributed Generators.	9
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162I	POWER SYSTEM PROTECTION	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

Objective of the course is to impart basic knowledge in computer relaying. It gives mathematical basis for relaying algorithms. This course explains transmission relaying algorithms and protection of transformers, machines and buses. It provides information about the hardware organization necessary for computer relaying.

ii) COURSE OUTCOMES

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

CO 1	Explain the concepts and mathematical basis for digital protective relaying.	Understand
CO 2	Explain various transmission relaying algorithms	Understand
CO 3	Identify suitable digital protection schemes for transformers, machines and buses.	Apply
CO 4	Select the necessary hardware requirements for relaying and control.	Apply
CO 5	Illustrate the various relaying schemes associated with travelling waves	Understand

iii) SYLLABUS

Introduction to computer relaying; Review of relaying practices.

Review of mathematical basis for protective relaying algorithms.

Transmission line relaying algorithms; Protection of transformers, Machines and buses.

Power transformer algorithms; digital protection of generators and motors; Hardware organization.

System relaying and control; Development in new relaying principles; recent developments in relaying.

iv) REFERENCES

1) Arun G. Phadke and James S Thorp, *Computer Relaying for Power Systems,* John Wiley & Sons Inc, New York.
2) Ravindra P. Singh, *Digital Power System Protection*, Prentice-Hall of India Pvt. Ltd., New Delhi, 2007.
3) Johns T., Salman S. K., Digital Protection for Power Systems, Peter Peregrinus Ltd., 1995.
4) Ali Abur& Antonio Gomez Exposito, Marcel Dekkerjnc, *Power System State Estimation-Theory and Implementation*.

v) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction to computer relaying:** Development and historical background, expected relay architecture, A-D converters, Anti –aliasing Filters, substation computer hierarchy. Review of relaying practices: functions of a protective system, Protection of transmission lines, Transformers, Reactors and generator Protection, Bus Protection, Performance of current and voltage transformers.	9
II	**Review of mathematical basis for protective relaying algorithms:** Fourier series, Orthogonal expansions, Fourier transforms, Discrete Fourier transforms, Introduction to probability and random processes, Kalman Filtering.	9
III	**Transmission line relaying algorithms:** Introduction, sources of error, relaying as parameter estimation, Symmetrical component distance relay, Protection of series compensated lines	8
IV	**Protection of transformers, Machines and buses:** Power transformer protection algorithms, digital protection of generators and motors, protection of buses. **Hardware organization:** Computers for relaying, substation environment, Industry environmental standards, counter measures against EMI, Redundancy and Back up.	9
V	**System relaying and control:** Measurement of frequency and phase, sampling clock synchronization, Application of phase measurements to static and dynamic state estimation, system monitoring. **Development in new relaying principles:** Travelling waves in single phase and three phase lines travelling waves due to faults, directional wave relay, Travelling wave distance relay, Differential Relaying with phasors, travelling wave differential relays, adaptive relaying fault location algorithms, recent developments in relaying.	10
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162J	SWITCH MODE POWER CONVERTERS	PEC	3	0	0	3	2022

i) COURSE OVERVIEW

This course aims to impart the knowledge to analyse the working and performance of various power electronic converters and to design converters. The course also imparts knowledge about Switched mode power supplies, its control methods and modelling.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Analyse the performance of various DC-DC converters	Analyse
CO 2	Analyse the performance of isolated converters	Analyse
CO 3	Compare the various control methods of Switch mode power Supplies.	Understand
CO 4	Apply the concepts of state space averaging in DC-DC converters	Apply
CO 5	Demonstrate the working of resonant converters	Understand

iii) SYLLABUS

Introduction to Linear Regulators and Switching Regulators- analysis of buck converter, boost converter and buck-boost converter in discontinuous current mode.

Analysis of fly back converter-continuous and discontinuous current mode of operation, Forward converter- Double ended forward converter-AC power supplies- power line disturbances- UPS.

Voltage mode control of SMPS- Current mode control of SMPS- Volt sec balance & small signal approximation-Boost converter analysis- Equivalent Circuit Modelling of Ideal Power Converters.

Introduction to AC modelling-Averaged AC modelling-Perturbation & Linearization-Modelling the pulse width modulator; State Space averaging- Circuit averaging and averaged switch modelling –Modelling of Flyback converter.

Introduction to Resonant converters- Load resonant converters-Resonant switch converters; Zero Voltage switching- resonant DC Link inverters with zero voltage switching – High frequency link integral half cyclo converter.

iv) REFERENCES

1) Abraham I Pressman , Switching Power Supply Design, McGraw-Hill Publishing Company
2) R. W. Erickson , Fundamental of Power Electronics, Chapman & Hall Publishers

3) C Rashid M.H., Power Electronics Circuits, Devices and Applications, 3rdEdition, Prentice Hall a. India, New Delhi, 2011.
4) Ned Mohan, Undeland, Robbins, Power Electronics: Converters, Applications and Design, 3rd Edition, John Wiley, 2003
5) Joshua Earnest, Tore Wizelius, Wind Power Plants And Project Development, PHI Learning, 2nd Edition, 2015
6) L. Umanand, Power Electronics: Essentials and Applications, Wiley, 2009 Rai. G.D, Solar Energy Utilization, Khanna Publishers, 5th Edition, 2014.
7) DC-DC Switching Regulator Analysis - D M Mitchel M cGraw-Hill Ltd, 1988.
8) Design of Magnetic Components for Switched Mode Power Converters- Umanand L and Bhatt S R New Age International, New Delhi, 2001

v) COURSE PLAN

Module	Contents	No. of hours
I	Introduction to Linear Regulators and Switching Regulators- principle of operation and analysis of buck converter analysis, inductor current ripple and output voltage ripple, design considerations, buck converter for discontinuous current operation, principle of operation and analysis of boost converter, inductor current ripple and output voltage ripple, inductor resistance effect, design considerations, boost converter for discontinuous current operation, principle of operation and analysis of buck boost converter analysis, inductors current ripple and output voltage ripple, buck-boost converter for discontinuous current operation	9
II	Principle of operation and analysis of fly back converter-continuous and discontinuous current mode of operation, principle of operation and analysis of forward converter, design considerations. Double ended forward converter AC power supplies, classification switched mode ac power supplies Resonant AC power supplies, bidirectional ac power supplies, multistage conversions, control circuits and applications. Introduction power line disturbances, power conditioners, uninterruptible Power supplies – applications	10
III	Voltage Mode Control of SMPS - Loop gain and Stability Considerations - Shaping the Error Amplifier gain versus frequency characteristics - Error amplifier Transfer function – Tran conductance Error amplifiers Current Mode Control of SMPS – Current Mode Control Advantages-Current Mode versus Voltage Mode Control of SMPS. Volt sec balance & small signal approximation-Boost converter analysis-Equivalent Circuit Modelling of Ideal Power Converters-DC transformer model-Modelling converter losses.	9
IV	Introduction to AC modelling-Averaged AC modelling-Perturbation & Linearisation-Modelling the pulse width modulator State Space Averaging – basic state space averaged model – State space averaging of non-ideal buck boost converter - Circuit averaging and averaged switch modelling –Modelling of flyback converter	8

V	Introduction to Resonant Converters – Classification of Resonant Converters – Basic Resonant circuit concepts – load resonant converters – resonant switch converters. Zero voltage switching, clamped voltage topologies – resonant DC Link inverters with zero voltage switching – High frequency link integral half cycle converter	**9**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162K	POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

This course aims to impart understanding about different renewable energy systems and power electronic circuits employed in the harnessing of energy from these systems and operation of grid-integrated energy systems.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Explain the power generation from Biomass, Ocean, Fuel cell and Hydrogen energy systems	Understand
CO 2	Illustrate the performance of solar photovoltaic system	Understand
CO 3	Model a stand-alone PV system based on required specifications.	Apply
CO 4	Illustrate the performance of Electrical Machines in Grid integrated wind energy conversion systems.	Understand
CO 5	Identify the various power electronic converters involved in WECS	Apply

2) iii) SYLLABUS

Environmental aspects of electric energy conversion, Qualitative study of various renewable energy systems.
Solar PV Systems-boost and buck-boost converters-Charge controllers- Batteries.
Design of a Standalone PV System -Selection of inverter, Battery sizing, Array sizing.
Grid Integrated solar system, MPPT algorithms of PV.
Wind Energy Conversion Systems- Principle of operation and analysis of SCIG, DFIG and PMSG- Operation of Standalone and Grid integrated WECS.
AC Voltage controllers -Grid interactive inverters-matrix converters.
Hybrid Renewable Energy systems- Type of Hybrid systems- MPPT algorithms of PV and WECS.

3) iv) REFERENCES

1) C.S.Solanki, — Solar Photovoltaic: Fundamentals Technologies And Applications, Prentice-Hall of India Pvt. Limited, 3rd Edition ,2015
2) Joshua Earnest, Tore Wizelius, Wind Power Plants and Project Development, PHI Learning, 2nd Edition, 2015
3) Rai. G.D, Solar Energy Utilization, Khanna Publishers, 5th Edition, 2014.

4) Rai. G.D, Non-conventional Energy Sources, Khanna publishers,6th Edition, 2017.
5) Ahmed: Wind energy Theory and Practice, PHI, Eastern Economy Edition, 2012.
6) Rashid M.H., Power Electronics Circuits, Devices and Applications, 3rd Edition, Prentice Hall a. India, New Delhi, 2004.
7) Kothari: Renewable Energy Sources and Emerging Technologies, PHI, Eastern Economy Edition, 2012.
8) Abbasi S. A. and N. Abbasi, Renewable Energy Sources and Their Environmental Impact, Prentice Hall of India, 2001.
9) Earnest J. and T. Wizelius, Wind Power Plants and Project Development, PHI Learning, 2011.
10) G.N. Tiwari: Solar Energy-Fundamentals, Design, Modelling and Applications, Narosa Publishers, 2002.
11) Leon Freris, David Infield, Renewable Energy in Power Systems, John Wiley &Sons., 2008
12) http://freevideolectures.com/Course/2342/Energy-Resources-and-Technology

v) COURSE PLAN

Module	Contents	No. of hours
I	Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment (cost-GHG Emission) Qualitative study of different renewable energy resources: Solar thermal system, ocean, Biomass, Fuel cell, and Hydrogen energy systems.	8
II	**Solar Photo Voltaic System**: PV cell characteristics & Equivalent circuit-PV Cell efficiency-Series and Parallel interconnection of cells- Solar photo voltaic system - Boost and buck-boost converters- Charge Controllers-types, Batteries-Battery Parameters-Battery Types. Ratings of PV module.	10
III	Design of a Standalone PV System -Selection of inverter, Battery sizing, Array sizing. Maximum Power Point Tracking-Hill climbing algorithm, incremental conductance method Grid Integrated solar system-single stage grid connected PV system	9
IV	**Wind Energy**: Wind Energy conversion system Principle of operation and analysis: SCIG, PMSG, and DFIG. Grid integrated PMSG and SCIG Based WECS-Grid Integrated DFIG WECS, Standalone operation of fixed and variable speed wind energy conversion systems. Power control, voltage regulation, frequency regulation in WECS	9
V	Three phase AC voltage controllers- AC-DC-AC converters- PWM Inverters, Grid Interactive Inverters - matrix converters. Hybrid Renewable Energy systems- Need for Hybrid Systems- Type of Hybrid systems. Grid connection Issues-Maximum Power Point Tracking algorithms of wind.	9
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162L	ADVANCED INSTRUMENTATION	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

The goal of the course is to provide an introduction to the field of Instrumentation and covers process variables and the various instruments used to sense, measure, transmit and control these variables. This course also introduces plant level automation, Petrinet models and various sensors used. The course concludes with a study of virtual instrumentation and review of a VI software.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Develop the mathematical model of various measurement systems	Apply
CO 2	Analyse the performance characteristics of zero, first and second order instruments.	Analyse
CO 3	Interpret the various sensors used in industrial instrumentation.	Understand
CO 4	Explain the various processes in plant level automation.	Understand
CO5	Develop programs based on the concept of virtual instrumentation	Apply

iii) SYLLABUS

Generalized performance characteristics of instruments.

General concept of transfer function, Dynamic response and frequency response studies, Response of a general form of instrument.

Plant level automation- process and instrumentation diagrams Performance modelling, Telemetry, Pneumatic Instrumentation; Reliability in Instrumentation and Control.

Petrinet models, Smart Sensors, Wireless sensors and Wireless Sensor network protocol.

Virtual instrumentation – Definition, flexibility – Block diagram and architecture of virtual instruments– Virtual instruments versus traditional instruments

Review of software in virtual instrumentation - VI programming techniques.

iv) REFERENCES:

1) B. D. Doeblin, *Measurement systems -Application and Design*, McGraw Hill New York.
2) John P. Bentley, *Principles of Measurement System*, Pearson Education
3) Walt Boyes, Butterworth-Heinemann, *Instrumentation Reference Book,* 3rd Edition, 2002.

4) J. W. Dally, W. F. Reley and K. G. Mc Connel, *Instrumentation for Engineering measurements*, 2nd Edition, John Wiley & sons Inc, New York, 1993.
5) Curtis D. Johnson, *Process Control Instrumentation Technology*, Prentice Hall of India Private Limited, New Delhi.
6) Dale E. Soberg, Thomson F Edgar, *Process Dynamics and Control*, 2nd Edition, Wiley.
7) K. B. Klaasen, *Electronic Measurement. And Instrumentation*, Cambridge University Press.
8) WaltenegusDargie& Christian Poella Bauer, *Fundamentals of Wireless Sensor networks*, Wiley Series.
9) Jun Zheng & Abbas Jamalipour, *Wireless sensor Networks- A Networking perspective*, Wiley
10) Silvano Donati, '*Electro-Optical Instrumentation: Sensing and Measurements with lasers*', PHI, 2010.

v) COURSE PLAN

Module	Contents	No. of hours
I	Generalized performance characteristics of instruments - Static characteristics, static calibration, memory, precision and bias, dynamic characteristics, development of mathematical model of various measurement systems. Classification of instruments based on their order.	9
II	General concept of transfer function (with special reference to measuring systems) Dynamic response and frequency response studies of zero order, first order and second order instruments. Response of a general form of instrument to a periodic input. Response of a general form of instrument to a transient input. Requirement of instrument transfer function to ensure accurate measurement.	9
III	Plant level automation- process and instrumentation diagrams Performance modeling — role of performance modeling- performance measures.	9
IV	Petrinet models- introduction to petrinets - basic definitions and analytical techniques, Smart Sensors, Wireless sensors and Wireless Sensor network protocol	8
V	Virtual instrumentation – Definition, flexibility – Block diagram and architecture of virtual instruments – Virtual instruments versus traditional instruments Review of software in virtual instrumentation - VI programming techniques, sub VI, loops and charts, arrays, clusters and graphs, case and sequence structures, formula nodes, string and file input / output	10
	Total hours	**45**

ourse Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162M	FINITE ELEMENT METHODS FOR ELECTRICAL MACHINES	PEC	3	0	0	3	2022

i) COURSE OBJECTIVE

Goal of this course is to expose the students to understand the basic electromagnetic field equations and the problem formulation for CAD applications and the concepts of Finite element and finite difference methods as applicable for Electrical Engineering.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Interpret the various electromagnetic field equations for problem formulation.	Understand
CO 2	Identify various methods like Finite Element Method and Finite Difference Method as applicable to Electrical Engineering.	Apply
CO 3	Analyze the performance of electrical machines using Finite Element Method and Variational Method	Analyse
CO 4	Interpret the organization of a typical CAD package for different applications.	Understand

iii) SYLLABUS

Need for Field Analysis based design- Recent Trends Mathematical Formulation of Field Problems- Development of Torque/Force

Electromagnetic Field Equations - Magnetic Vector/Scalar Potential - Electrical Vector/Scalar Potential- Inductances - Maxwell Equations - Laplace and Poissons Equations

Philosophy of FEM- Differential/Integral Equations - Finite Difference Method - Finite Element Method- boundary conditions.

Rayleigh Ritz and Galerkin Approach to finite Elements- Normal gradient boundary conditions- Forced and natural boundary conditions.

Elements of CAD Systems - Preprocessing - Modeling - meshing - Material Properties - Boundary Conditions - Setting up Solutions- The electric field-finite element analysis.

iv) REFERENCES

1) Sheppard J. Salon, Kluwer, *Finite Element Analysis of Electrical Machines*, Springer-Verlag New York Incorporation,2019.
2) Krishna Moorthy C. S., *An Introduction to Computer Aided Electromagnetic Analysis, Vector Field Finite Element Analysis*, Tata McGraw Hill Publishing Company Limited, New Delhi, 2014.
3) Peter P Silvester. Ronald L Ferrari. *Finite Elements for Electrical Engineers*, Cambridge University Press, 2012.

4) Rantajeevan H. Hoole S., *Computer Aided analysis and design of electromagnetics devices*, Elsevier Science Publishing company, New York, 2005.
5) Lowther D. A. and Silvester P. P., *Computer Aided design in Magnetics*, Springer Verlag, Berline Heidelberg, New York, 2017.
6) Nicola Bianchi, *Electrical Machine Analysis Using Finite Elements,* CRC Press,2017.

v) COURSE PLAN

Module		Contents	No. of hours
I		**Introduction:** Conventional design Procedures - Limitations - Need for Field Analysis based design - History of development and Applications - Recent Trends Mathematical Formulation of Field Problems: Review- Development of Torque/Force.	9
II		**Electromagnetic Field Equations** - Magnetic Vector/Scalar Potential - Electrical Vector/Scalar Potential - Stored Energy in Field Problems - Inductances - Maxwell Equations - Laplace and Poissons Equations - Energy Functional. Numerical Problems.	9
III		**Principle of Energy Conversion Philosophy of FEM**: Mathematical Models - Differential/Integral Equations - Finite Difference Method -Band Matrix method- Finite Element Method - Energy Minimization - Field problems - Discretization - Shape Functions - Stiffness Matrix. Numerical Problems.	9
IV		**Variational Method** - Direct and Indirect Method-Moment Method, Point Collocation, Sub domain Collocation, Least Squares. Weighing Functions. **Rayleigh Ritz and Galerkin Approach to finite Elements** - Normal gradient boundary conditions- Forced and natural boundary conditions- - Galerkin Method for poison equation -Numerical example.	9
V		**Solution Techniques CAD Packages and Design Applications**: Elements of CAD Systems - Preprocessing - Modeling - meshing - Material Properties - Boundary Conditions - Setting up Solutions.	9

		Electric and Magnetic Fields in a co-axial cable - The magnetic field - The electric field-finite element analysis - Case study of machines. Thermal modelling of power devices.	
		Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162N	EHVAC AND DC TRANSMISSION	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

To enable the student, gain a fair knowledge on the concepts and technology of Extra High Voltage DC and AC Transmission.

ii) COURSE OUTCOMES

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

CO 1	Illustrate the configuration of HVDC systems.	Understand
CO 2	Analyse the performance of converter circuits for HVDC systems.	Analyse
CO 3	Identify reactive power requirements in converter circuits and the remedial measures for harmonic reduction.	Apply
CO 4	Explain the protection schemes in HVDC substations and the configurations of earth electrodes.	Understand
CO 5	Apply the concept of voltage gradient in corona loss calculation.	Apply
CO 6	Explain the insulation requirement and insulation coordination in substations.	Understand

iii) SYLLABUS

EHV AC transmission- interconnected AC networks-HVDC transmission system- Power flow in AC and HVDC lines-steady state Ud/Id characteristics. Converter circuits- analysis of converters- control characteristics; Harmonics and filters. Reactive power requirements in HVDC substations- planning of HVDC; DC line oscillations and line dampers-over voltage protection; Earth electrode; EHV AC Transmission; Corona; Insulation requirements of EHV AC and DC transmission lines; insulation coordination; switching over voltage.

iv) REFERENCES

1) Rao.S, *EHV AC and HVDC Transmission Engineering & Practice*, Khanna Publishers,3rd Edition, 1993.
2) Kimbark.E.W, *Direct Current Transmission Volume*, John Wiley, New York, 1st Edition, 1971
3) Padiyar.K.R, *HVDC Power Transmission Systems*, Wiley Eastern Ltd, 3rd Edition,2017.
4) Rakosh Das Begamudre, *EHV AC Transmission Engineering*, New Age International Pvt. Ltd., 3rd Edition 2006.

v) COURSE PLAN

Module	Contents	No. of hours
I	**EHVAC and HVDC systems:** EHV AC transmission-configuration-features, intermediate substations-applications; interconnected AC networks, HVDC system-classification-configuration, equipment in HVDC substations, Major HVDC systems in India, EHV AC vs. HVDC-economic comparison, HVDC power flow, power conversion principle, power loss in DC system, steady state Ud/Id characteristics.	0
II	**Converter circuits**: single phase and three phase circuits, analysis of bridge converter, with and without overlap, control characteristics, constant minimum ignition angle control, constant current control, extinction angle control.	9
III	**Harmonics**: characteristic harmonics in AC; non characteristic harmonics in AC, means of reducing harmonics-filters-single frequency and double frequency-tuned filters, DC harmonic filter, telephone interference. **Reactive power requirements in HVDC substations**: effect of delay angle and extinction angle, significance of short circuit ratio for planning of HVDC links.	9
IV	**Protection:** DC line Oscillations and line dampers, Over voltage protection, DC lightning arresters, DC circuit breakers- basic concepts, types and characteristics. **Electrode**s: location and configuration, earth return, materials of anode, sea electrode, shore electrode, troubles by earth currents and remedial measures.	8
V	**EHV AC Transmission:** Components of transmission system-voltage gradients of conductor-single and bundled conductor. **Corona:** Corona and corona losses in EHPEC and HVDC-critical surface gradient-Peeks law-critical disruptive voltage and critical electric stress for visual corona. **Insulation requirements:** Insulation requirements of EHV AC and DC transmission lines - Electrostatic field of EHV lines-biological effects-live wire maintenance **Insulation co-ordination:** insulation for power frequency-voltage-switching, over voltage-lightning performance.	9
	Total hours	**45**

ourse Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162O	POWER QUALITY IN ELECTRICAL SYSTEMS	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

Goal of this course is to impart knowledge about various power quality issues in electrical systems and methods to control them.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO1	Illustrate various power quality issues in power distribution systems	Understand
CO2	Identify sources of harmonics in power distribution systems	Apply
CO3	Model various components in distribution systems under non-sinusoidal conditions.	Apply
CO4	Apply harmonic analysis methods such as Fourier transform and window function in power systems.	Apply
CO5	Classify the different harmonic elimination techniques.	Understand

iii) SYLLABUS

Power quality issues in distribution systems, Need for power quality monitoring, IEEE guides, standards and recommended practices, Modeling of networks and components under non-sinusoidal conditions, Harmonic Analysis, Effects of Power System harmonics on Power System equipment and loads, Harmonic elimination, Dynamic voltage restorers and UPQC control strategies.

iv) REFERENCES

1) R. C. Durgan, M. F. Me Granaghen, H. W. Beaty, “Electrical Power System Quality”, McGraw-Hill, 3rd Edition, 2017.
2) Jose Arillaga, Neville R. Watson, “” Power System Harmonics”, Wiley Publications, 2nd Edition ,2007.
3) C. Sankaran, “Power Quality”, CRC Press, Edition 1,2001.
4) G. T. Heydt, “Power Quality”, Stars in a circle publication, 1st Edition ,1991.
5) Math Bollen H.J., “Understanding Power Quality Problems-Voltage sag & Interruptions”, IEEE Press, 2000.
6) J. B. Dixit & Amit Yadav, “Electrical Power Quality”, Laxmi Publications, Edition1, 2010.

v) COURSE PLAN

Module	Contents	No. of hours
I	Power Quality - Power quality issues in distribution systems - Sources and Effects of power quality problems, Power quality monitoring: Need for power quality monitoring. Types of power quality disturbances - Voltage sag (or dip), Transients, short duration voltage variation, Long duration voltage variation, voltage imbalance, waveform distortion, and voltage flicker.	**9**
II	IEEE guides, standards and recommended practices. Harmonics - mechanism of harmonic generation-harmonic indices (THD, TIF, DIN, C – message weights - Power Quality Costs Evaluation - Causes and effects of power quality disturbances. Harmonic sources - SMPS, Three phase power converters, arcing devices, saturable devices, fluorescent lamps.	**9**
III	Modeling of networks and components under non-sinusoidal conditions-transmission and distribution systems-shunt capacitors-transformers-electric machines-ground systems- loads that cause power quality problems. Modeling of transformers-electric machines-ground systems-loads that cause power quality problems.	**9**
IV	Harmonic Analysis - Fourier series and coefficients, the Fourier transforms, discrete Fourier transform, fast Fourier transform, Window function. Effects of Power System harmonics on Power System equipment and loads.	**9**
V	Harmonic elimination - Design and analysis of filters to reduce harmonic distortion – Power conditioners, passive filter, active filter - shunt, series, hybrid filters, Computation of harmonic flows-Voltage regulation- devices for voltage regulation- capacitors for voltage regulation.	**9**
	Total hours	**45**

Course Code	Course Name	Categor y	L	T	P	Credit	Year of Introduction
22EE162P	HYBRID AND ELECTRIC VEHICLES	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

Goal of this course is to familiarize a comprehensive overview of Electric and Hybrid Electric Vehicle and it also discusses how to choose proper energy storage systems for vehicle applications. It gives an insight into the electric propulsion unit and its control for application of electric vehicles. It also intends to deliver design of Hybrid Electric Vehicle and various communication protocols and technologies used in vehicle networks.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Apply the change in acceleration and angular acceleration of rigid bodies in vehicle dynamics.	Apply
CO 2	Examine the various hybrid and electric drive train configurations and its power flow control depending on resources.	Analyse
CO 3	Analyze the energy storage systems for vehicle applications	Analyse
CO 4	Develop different power train schemes for hybrid and electric vehicles.	Apply
CO 5	Interpret various communication protocols and technologies used in vehicle networks.	Understand

iii) SYLLABUS

Introduction to Hybrid Electric Vehicles, Conventional Vehicles, Basics of vehicle performance: Dynamics of electric and hybrid vehicles vehicle.

Hybrid Electric Drivetrains- various hybrid drive-train topologies, power flow control.

Electric Propulsion unit, Configuration and control of DC Motor, Induction Motor drives, Permanent Magnet Motor drives, Switched reluctance motor.

Energy Storage Requirements in Hybrid and Electric Vehicles, Hybridization of different energy storage devices.

Sizing the drive system, Matching the electric machine and the internal combustion engine. Design of a Hybrid Electric Vehicle and Battery Electric Vehicle. In vehicle networks, Energy Management Strategies.

iv) REFERENCES

1) Iqbal Hussein, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 2003.

2) Gianfranco Pistoia, *Electric and Hybrid Vehicles: Power Sources, Models, Sustainability, Infrastructure and the Market,* Elsevier,2010.
3) Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design*, CRC Press, 2004.
4) Sheldon S. Williamson, *Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles*, Springer, 2013.
5) James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.
6) Chris Mi , M. Abul Masrur, *Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives,* Second Edition, John Wiley & Sons Ltd,2017.
7) A. E. Fuhs, Hybrid Vehicles and the Future of Personal Transportation, CRC Press, 2009.
8) C.C. Chan and K.T. Chau, *Modern Electric Vehicle Technology,* OXFORD University Press, 2001.

v) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction to Hybrid Electric Vehicles**: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles. Conventional Vehicles: Basics of vehicle performance, vehicle power source characterization, transmission characteristics, mathematical models to describe vehicle performance, Maximum Tractive effort.	8
II	**Hybrid Electric Drive-trains**: Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies. Electric Drive-trains: Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies.	9
III	**Electric Propulsion unit**: Introduction to electric components used in hybrid and electric vehicles, Configuration and control of Induction Motor drives, Configuration and control of Permanent Magnet Motor drives, Configuration and control of Switched Reluctance Motor drives.	9
IV	**Energy Storage**: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices.	9
	Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology, Case Studies: Design of a Hybrid Electric Vehicle (HEV), Design of a Battery Electric Vehicle (BEV). **Communications,** supporting subsystems: In vehicle networks- CAN, ISO-OSI Seven layer Model. Energy Management Strategies: Introduction to	10

V	energy management strategies used in hybrid and electric vehicles, classification of different energy management strategies. EV Charging Technologies: Standards, Conductive and Inductive charging methods, Concept of V2G, G2V, V2B, V2V. EV Charging infrastructure: Policy, Impacts of integration of EVs in Smart Grid.	
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162Q	SCADA SYSTEMS AND APPLICATIONS	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

Goal of this course is to familiarize SCADA systems, its components, architecture, communication and applications.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Explain the operating principle of Modern SCADA systems.	Understand
CO 2	Illustrate the different components of SCADA systems and its architecture.	Understand
CO 3	Illustrate the communication architecture and protocols used in SCADA systems.	Understand
CO 5	Identify the operation and control schemes of interconnected power systems using SCADA.	Apply

iii) SYLLABUS

Introduction to SCADA systems, Principle of Modern SCADA Systems, Monitoring and supervisory functions, Application.

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

SCADA Architecture: Various SCADA architectures, advantage and disadvantage, SCADA Communication: Various industrial communication, Open standard communication protocols.

Operation and control of interconnected power system, Automatic substation control, SCADA configuration, Energy management system, System operating states, System security, state estimation, SCADA Applications

iv) REFERENCES

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', Newnes Publications, Oxford, UK,2004
3) David Bailey, Edwin Wright, Practical SCADA for Industry, Newnes (an imprint of Elsevier), 2003
4) KLS Sharma, Overview of Industrial Process Automation, Elsevier Publication

v) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction to SCADA systems**: Evolution of SCADA. Fundamental Principle of Modern SCADA Systems, Monitoring and supervisory functions. Application area of SCADA. Consideration and benefits of SCADA system	8
II	**SCADA System Components**: Remote Terminal Unit-(RTU), Intelligent Electronic Devices (IED), PLC: Block diagram, programming languages, Ladder diagram, Functional block diagram, Applications, Interfacing of PLC with SCADA. Communication Network SCADA Server, SCADA/HMI Systems	10
III	**SCADA Architecture**: Various SCADA architectures, advantages and disadvantages of each system - Single unified standard architecture, IEC 61840 SCADA / HMI Systems	9
IV	**SCADA Communication**: Various industrial communication technologies -wired and wireless methods and fiber optics-Open standard communication protocols	9
V	**Operation and control of interconnected power system** -Automatic substation control, SCADA configuration-Energy management system -System operating states System security, state estimation SCADA Applications: Utility applications-Transmission and Distribution sector operations, monitoring, analysis and improvement.	8
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162R	SPECIAL ELECTRICAL MACHINES AND DRIVES	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

Goal of this course is to give an exposure to the concepts of various types of special electrical machines and their control scheme.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Explain the various types of special electrical machines	Understand
CO 2	Identify suitable electric motors for different applications based on performance characteristics.	Apply
CO 3	Analyze various special electrical machines by the selection, synthesis and implementation of the established principles, procedures and practices.	Analyse
CO 4	Analyze various schemes for the control of special electrical machines.	Analyse

iii) SYLLABUS

Stepper motor- Modes of excitation, torque production in variable Reluctance stepping motor, Static and Dynamic characteristics, Drive systems and circuit, Microprocessor based controller.

Switched reluctance motor- Constructional features, Torque equation, Power controllers, Characteristics and control.

Permanent Magnet Brushless DC motor- Commutation in DC motors, Hall sensors, Optical sensors, Multiphase Brushless motor, Square wave permanent magnet brushless motor drives.

Permanent Magnet Synchronous motor-Phasor diagram, Power controllers, Torque speed characteristics, Self control, Vector control, Current control schemes. Sensor less control.

iv) REFERENCES

1) Kenjo T, Sugawara A, Stepping Motors and Their Microprocessor Control, Clarendon Press, Oxford, 1994
2) Miller T J E, Switched Reluctance Motor and Their Control, Clarendon Press, Oxford,1993.
3) Miller T J E, Brushless Permanent Magnet and Reluctance Motor Drives, Clarendon Press, Oxford, 1989.
4) Kenjo T, Power Electronics for the Microprocessor Age, Oxford University Press,1990.
5) R Krishnan, Electric Motor Drives – Modeling, Analysis and Control, PHI, 2003.

v) COURSE PLAN

Module	Contents	No. of hours
I	**Reluctance Motors:** Principle of Operation-Conventional and special types of rotor construction analysis and equivalent circuit-phasor diagram-circular loci of current and voltage components maximum pf-power expression pull-in characteristics-factors affecting pulling in applications	8
II	**Switched Reluctance Motors** - Constructional features, principle of operation. Torque equation, Power controllers, Characteristics and control. Microprocessor based controller. Sensor less control. Synchronous Reluctance Motors-Constructional features: axial and radial air gap Motors. Operating principle, reluctance torque – Phasor diagram, motor characteristics.	**10**
III	**Stepper Motors** - Constructional features, principle of operation, modes of excitation, single phase stepping motors, torque production in variable Reluctance (VR) stepping motor, Static and Dynamic characteristics, Drive systems and circuit for open loop control, Closed loop control of stepping motor, microprocessor based controller.	**9**
IV	**Permanent Magnet Brushless DC Motors** - Commutation in DC motors, Difference between mechanical and electronic commutators, Hall sensors, Optical sensors, Multiphase Brushless motor, Square wave permanent magnet brushless motor drives, Torque and emf equation, Torque-speed characteristics, Controllers-Microcontroller based control. Sensorless control.	**9**
V	**Permanent Magnet Synchronous Motors** - Principle of operation, EMF, power input and torque expressions, Phasor diagram, Power controllers, Torque speed characteristics, Self control, Vector control, Current control schemes. Sensor less control.	**9**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE162S	ANALYSIS, DESIGN AND GRID INTEGRATION OF PHOTOVOLTAIC SYSTEMS	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

Goal of this course is to analyze and design the grid integration of photovoltaic systems. This course aims to impart knowledge about fundamentals concepts of solar cells and to analyze different techniques for maximum power extraction from the PV system. This course also provides the students with the knowledge of the different PV based applications and their system design and its impacts caused by the integration of distributed renewable generation in the power system.

ii) COURSE OUTCOMES

CO 1	Illustrate the performance of solar cells under various atmospheric conditions	Understand
CO 2	Model a solar PV system as per the required specifications	Apply
CO 3	Identify suitable MPPT algorithms for PV systems	Apply
CO 4	Select various protection schemes for grid interactive PV Systems	Apply
CO 5	Explain the various control schemes for solar PV Systems	Understand

iii) SYLLABUS

Generation of Photo Voltage –Solar Cell Characteristics. Construction: Upper Limit of Cell Parameters- Losses in Solar Cells - Diode Equivalent Model

Solar Cell Fundamentals: Solar PV modules: PV Modelling: Equivalent circuit of PV cell. Control of PV System: Effect of Variation of Solar Insolation and Temperature – Partial Shading.

Batteries for PV systems –MPPT Algorithms: Perturb and Observe- Incremental Conductance, Mechanical Tracking - Single Axis Tracking – Dual Axis Tracking. Power converters and control for PV system.

Grid Synchronization: Micro-grids, and frequency/voltage control in islanded mode of operation, distributed storage and smart grid concepts. Stand-alone PV system, Grid Interactive PV System, Hybrid solar PV system.

Structure of Grid Imposed Frequency VSC system: Real-/ Reactive Power Controllers - Current Mode Versus Voltage Mode Control

iv) REFERENCES

1) A K Mukerjee, Niveditha Thakur: Photovoltaic Systems Analysis and Design, PHI, 2011.
2) Chetan Singh Solanki, Solar Photovoltaics Fundamentals, Technologies and Applications, PHI, 3rd Edition, 2015.
3) Amir Naser Yazdani and Reza Iravani: Voltage - Sourced Converters in Power Systems modeling, control and Applications, WILEY, IEEE Press, 2010.
4) H.K.V. Lotsch, Adolf Goetzberger, Volker U. Hoffmann, Photovoltaic Solar Energy Generation Springer Series in Optical Science, 2005.
5) Antonio Luque and Steven Hegedus: Handbook of Photovoltaic Science and Engineering, WILEY, 2nd Edition, 2010.

v) COURSE PLAN

Module	Contents	No. of hours
I	Solar Cells: Generation of Photo Voltage – Light Generated Current – I V Equation of Solar Cells- Solar Cell Characteristics-Upper Limit of Cell Parameters- Losses in Solar Cells - Diode Equivalent Model. Effect of Variation of Solar Insolation and Temperature on Efficiency.	9
II	Solar PV Modules from Solar Cells - Series and Parallel Connection of Cells – Design and Structure of PV Module – Number of Solar Cells in a Module – Wattage of Modules- PV Module Power Output - I- V Equation of PV Module - Ratings of PV Module – I-V Curve and P-V Curve of Module. Effect of Variation of Solar Insolation and Temperature – Partial Shading of a Solar Cell and a Module.	9
III	Batteries for PV systems – Factors affecting battery performance MPPT Algorithms: Perturb and Observe- Incremental Conductance, Mechanical Tracking - Single Axis Tracking – Dual Axis Tracking. Design PV powered DC fan and pump without battery- Design of Standalone System with Battery and AC or DC Load.	9
IV	A Grid Interactive PV System - Phase, Frequency Matching and Voltage Consideration – Operation of a Grid Interactive Inverter – Protection Against Islanding and Reverse Power Flow – AC Modules- Design of EMI Filters. Over current protection of solar PV power system, Selective fuse links for PV String protection, PV fuse selection flow chart, Fuse rating for PV Applications.	9
V	Control in αβ Frame - Structure of Grid Imposed Frequency VSC system – Real-/ Reactive Power Controllers - Current Mode Versus Voltage Mode Control - Dynamic Model of Real-/ Reactive Power Controllers - Current Mode Control of Real/ Reactive Power	9
	Total hours	**45**

SEMESTER II SYLLABUS

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE160A	ELECTRIC DRIVES	DCC	3	0	0	3	2022

i) COURSE OBJECTIVES

Goal of this course is to impart knowledge about electric drive system mechanics, converters and development of new drive control strategies such as field oriented / vector control, DTC, SVPWM etc. for the control and operation of DC and AC motor drives.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO1	Illustrate multi quadrant operation of electric drives	Understand
CO2	Apply various control strategies using Power Converters for DC drives.	Apply
CO3	Identify the various speed control methods for Induction Motor Drives.	Apply
CO4	Select suitable VSI/ CSI fed synchronous motor drives for various applications	Apply
CO5	Explain the control schemes for BLDC motor drives.	Understand

iii) SYLLABUS

Review of introductory concepts of drives- Block Diagram of Drive, Speed torque characteristic of load, Multi-quadrant operation of Drives, Stability of drive systems, Closed loop speed control of DC motor drives.

DC motor drives and its Operational Strategies- Transfer functions of controlled rectifiers and choppers, Four quadrant operation of dc drives with Dual converter, Four quadrant operation of dc-dc converter fed drives.

Induction Motor Drives: Steady state equivalent circuit of 3-phase Induction motor—Speed control techniques of induction motor, Slip power recovery schemes

AC Drives and its Operational Strategies - Space Vector Model of Induction motor, Basic transformations in reference frame theory- Field Orientation Principle- Vector control- FOC, DTC.

Synchronous motor drives – VSI fed synchronous motor drives – V/f control and vector control, CSI fed synchronous motor drives, Vector control of Permanent Magnet Brushless DC Motors.

iv) REFERENCES

1. Dubey G. K., *Fundamentals of Electrical Drives*, CRC Press, 2002.
2. Bimal K. Bose, *Modern Power Electronics and AC drives*, Pearson Education, Asia 2003.
3. Werner Leonhard, *Control of Electrical Drives*, Springer, 3rd Edition 2001.
4. Bin Wu, *High Power Converters and AC Drives*, Wiley-IEEE Press, 2nd Edition, 2017.

5. Dr. Bimbra P. S., *Power Electronics*, Khanna Publishers, 4th Edition, 2001.
6. Murphy M. D., *Thyristor Control of AC Drives*, Elsevier Science Technology Books,1973.
7. De N. K. and Sen P. K., *Electric Drives*, Prentice Hall of India, 2006.
8. Ned Mohan, Tore M., Undeland and William P Robbins, *Power Electronics Converters Applications and Design*, John Wiley and Sons, 2009.
9. Vedam Subrahmanyam, *Electric Drives*, Mc Graw Hill Education, New Delhi, 2011.
10. Fitzgerald, Kingsley and Umans, *Electric Machinery*, Tata McGraw hill, 4th Edition,1988.

V) COURSE PLAN

Module	Contents	No. of hours
I	**Drive system mechanics**: Steady state characteristics of different types of motors and loads, Multi-quadrant operation of electric drive. Stability of drive systems DC drives: Separately excited dc motor drives – dynamic behaviour in constant flux mode, Closed-loop control of separately excited DC motor drives – transfer functions of motor.	9
II	**Transfer functions of controlled rectifiers and choppers**: two quadrant operation with controlled single-phase converter- continuous and discontinuous current operation and three-phase converters, Four quadrant operation of DC drives with Dual converter, Four quadrant operation of DC-DC converter fed drives - Single quadrant, two quadrant and four quadrant choppers.	9
III	**Induction Motor Drives**: Steady state equivalent circuit of 3phase Induction motor - Stator voltage control – constant V/f speed control with VSI - V/f control with slip compensation – Slip power recovery schemes – sub synchronous and super synchronous speed operation (Static Kramer and Static Scherbius drives). Concept of Space Vectors – Evaluation of dwell times - Basic transformations in reference frame theory	9
IV	**Vector Control of Induction Motor**: Field orientation Principle-Direct and indirect vector control. Direct Torque Control (DTC) of Induction Motor-Basic concepts and block diagram - CSI fed induction motor drives.	9
V	**Synchronous motor Drives**: VSI fed synchronous motor drives – V/f control and vector control-Line Commutated Inverter fed Synchronous motor drives; CSI fed synchronous motor drives. Permanent Magnet Brushless DC Motors. Speed Control of Trapezoidal EMF machines (Brushless DC motors) - Basic principles and Control schemes.	9
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE161C	DESIGN PRINCIPLES OF POWER CONVERTERS	PCC	3	0	0	3	2022

i) COURSE OBJECTIVES

This course gives basic knowledge in the design of power converter circuits. It imparts knowledge to choose power devices for a particular application. It explains the thermal design of power converters. This course gives a good insight into the design of high frequency transformers and inductors. It provides information about parasitic and noise in power converter circuits and various techniques to minimise them. This course provides knowledge about gate driver circuits. It gives knowledge in various protection schemes used with power electronic circuits. This course also provides basics knowledge in EMI/EMC issues.

ii) COURSE OUTCOMES

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

CO 1	Develop heat sink for power converters.	Apply
CO 2	Select high frequency transformer and inductor for power converter circuits.	Apply
CO 3	Apply various techniques to minimize the effects of parasitic bus inductance	Apply
CO 4	Analyse gate drive circuit for power converter circuits.	Analyse
CO 5	Explain the various thermal protection schemes and EMI issues in power converters.	Understand

iii) SYLLABUS

Thermal Design of Power modules; Magnetics design based on area-product approach; Techniques in bus-bar design for medium and high-power converters to minimise dc-bus loop inductance; Idea of ground loops; Gate drive circuit design; Popular gate drive circuits for MOSFETs, SCRs, BJTs and IGBTs; Thermal protection de-saturation schemes; Basics of EMI/EMC issues.

iv) REFERENCES

5) Umanand L, *Power Electronics: Essentials & Applications*, New Delhi, Wiley India Pvt. Ltd., 2009.
2) Ned Mohan, Undeland, Robbins, *Power Electronics: Converters, Applications and Design*, 3rd Edition, John Wiley, 2006.
3) AN-978, *HV Floating MOS-Gate Driver ICs*, International Rectifiers, 2003.
4) *Mitsubishi Semiconductors Power Module application notes*, Mitsubishi Electric global, 1998.

v) COURSE PLAN

Module	Contents	No. of hours
I	**Thermal Design** Power circuit design, selection of power devices, losses, Thermal design- Typical examples based on DC-DC converters and bridge inverters. Thermal design with cooling fan.	9
II	**Magnetic design** Magnetic design based on area-product approach, Design of inductors, transformers. Typical examples based on buck converter and flyback converter.	9
III	**Parasitics and noise in PE** Parasitics and their effects and tackling parasitics, leakage inductance and bus-bar inductance, Power circuit assembly, techniques in bus-bar design for medium and high-power converters to minimise dc-bus loop inductance - idea of ground loops and their effects in converter operation.	9
IV	**Gate drive circuit design** Necessity of gate driver circuits, popular gate drive circuits for SCRs, MOSFETs, and IGBTs. Gate drive ICs: Typical design using IC IR 2110, isolation, and techniques of isolation opto-isolator based gate drive design, pulse transformer-based design	8
V	**Protection of Power converters** Thermal protection, thermal sensor-based protection, short-circuit and over-current protection in IGBTs using de-saturation schemes. **Basics of EMI/EMC issues** Types of EMI, conductive and radiated EMI- basic solutions, Differential mode filters, Common mode filters, System integration.	10
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE165A	SOLAR AND WIND ENERGY CONVERSION SYSTEMS	IEC	3	0	0	3	2022

i) COURSE OVERVIEW

This course aims to impart the knowledge of renewable energy sources and electric mobility as sustainable development. The students will be familiarised with the major aspects of solar and wind energy conversion systems. This course also aims at providing the fundamental information in modelling the energy conversion systems and hybrid electric vehicles.

ii) COURSE OUTCOMES

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

CO 1	Explain various solar thermal systems.	Understand
CO 2	Analyse the design aspects of solar photovoltaic system sizing	Analyse
CO 3	Explain the concepts involved in wind energy systems.	Understand
CO 4	Compare the performance of Standalone and Grid connected Wind Energy Conversion Systems	Analyse
CO 5	Illustrate the application of renewable energy in Electric Vehicles	Understand

iii) SYLLABUS

Solar Energy - Solar radiation geometry – Solar Thermal Systems - Solar Thermal Collectors - Solar Water Heaters - Solar thermal power plants.
Solar photovoltaic systems - Characteristics - Types of solar cells - PV Module - Block diagram of SPV system – MPPT – Design of SPV - Modelling of SPV in MATLAB.
Wind Energy **-** Wind power and its sources - Dynamics of Turbine blade - Classification of Wind turbines.
Wind Energy Conversion Systems WECS – Principles - Classification of WECS - Wind Electric Generation Systems - Interfacing WECS and PV systems with Grid – Practice Problems. Modelling of Wind Turbine in MATLAB.
Hybrid Electric Vehicles – Introduction – Types – Plug-in Hybrid Electric Vehicle – Grid integration issues with renewable resources – V2G, V2H, V2B, V2H – EV charging standards.

iv) REFERENCES

1) Earnest J., Wizelius T., *Wind Power Plants and Project Development*, Prentice Hall of India, Learning Private Limited, 2nd edition, 2015.
2) Godfrey Boyle, *Renewable Energy: Power for a sustainable future*, Oxford University Press, 2012.
3) Rai G. D., *Non-conventional Energy Sources*, Khanna publishers, 2011.
4) Iqbal Hussein, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 2003.
5) Gary L. Johnson, *Wind Energy System*, Prentice Hall, 1985.
6) Solanki C. S., *Solar Photovoltaics: Fundamentals Technologies and Applications*, Prentice-Hall of India Pvt. Limited, 3rd edition, 2015.
7) Rai G. D, *Solar Energy Utilization*, Khanna Publishers, 1995.

Kastha D., Banerjee S., Bhadra S. N., *Wind Electrical Systems*, Oxford University Press, New Delhi, 2005.

8) Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design*, CRC Press, 2004.
9) Rashid M. H., *Power Electronics Circuits, Devices and Applications*, 4th edition, Pearson Education, 2017.

v) COURSE PLAN

Module	Contents	No. of hours
I	**Solar Energy** – Solar radiation geometry – solar angles, day length, angle of incidence. Measurement of solar radiation - pyranometer, pyrheliometer. **Solar Thermal Systems** - Solar Thermal Collectors - Types of collectors - Flat Plate and Concentrating type. **Solar photovoltaic systems** - Solar Cell - Basic structure - IV Characteristics - Types of solar cells - Losses in a solar cell - PV Module-Specifications.	9
II	**SPV system** – Components - Principle of operation. Standalone PV system-Grid Interactive PV System - hybrid PV system. Maximum Power Point Tracking. Design of a Standalone PV System-Selection of inverter, Battery sizing, Array sizing. Solar PV installations and its statutory requirements. Modelling of SPV in MATLAB platform.	9
III	**Wind Energy -** Wind power and its sources - site selection - Wind energy Scenario in World and India. Derivation of electrical power output in the wind - Betz limit - wind characteristics - Dynamics of Turbine blade - lift and drag forces. Classification of Wind turbines - Advantages and limitations of wind energy conversion systems.	9
IV	**Wind Energy Conversion Systems (WECS)** – Principles - Classification of WECS - Stand-alone WECS. Grid connected systems: WT-IG, WT-DWIG, WT-PMG and WT-VSIG - Comparison of performance. Interfacing WECS and PV systems with Grid – Problems.	9

	Modelling of Wind Turbine in MATLAB platform.	
V	**Application of Solar and Wind Energy Conversion Systems** –Types of EVs – Vehicle fundamentals - Hybrid Electric Drive Train – Plug-in Hybrid Electric Vehicles – Environmental Implications – Storage Technologies – Grid integration issues of renewable energy sources. Concept of V2G, G2V, V2H and V2B. EV charging standards – E-mobility Indian Road Perspective and scenarios - Case study.	**9**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE165B	ELECTRIC VEHICLE TECHNOLOGY	IEC	3	0	0	3	2022

i) COURSE OBJECTIVES:

The main goal of this course is to expose the students to the fundamental concepts and trends in electric vehicles and hybrid electric vehicles and it also discusses how to choose proper energy storage systems for vehicle applications. It gives an insight into the electric propulsion unit and its control for application of electric vehicles. It also intends to deliver various energy management strategies, charging technologies and standards used in vehicle networks.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Develop the dynamic equations for improving the vehicle performance.	Apply
CO 2	Illustrate the power control topologies and electric propulsion systems used in hybrid and Electric vehicles.	Understand
CO 3	Select various energy storage devices used in hybrid and electric vehicles based on their performance requirements.	Apply
CO 4	Identify the key vehicle system requirements for component sizing	Apply
CO 5	Explain the communication protocol, energy management strategies and charging technologies used in hybrid and electric vehicles.	Understand

iii) SYLLABUS

Conventional Vehicles, Basics of vehicle performance, Basic Architecture of hybrid traction, Power flow control.

Electric Propulsion unit, Configuration and control of DC motor drives, Induction Motor drives, PM and SRM motor drives.

Energy Storage Requirements in Hybrid and Electric Vehicles, Battery, fuel cell, flywheel and supercapacitor-based energy storage.

Design of electric and hybrid electric vehicle, sizing of components.

Communication Systems, Energy Management Strategies, EV charging technologies and policies.

iv) REFERENCES

1) Iqbal Husain: *Electric and Hybrid vehicles: Design Fundamentals,* CRC press 2003.
2) Ehsani M., *Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design*, CRC Press, 2005.
3) Gianfranco Pistoia, *Electric and Hybrid Vehicles: Power Sources, Models, Sustainability, Infrastructure and the Market,* Elsevier,2010.
4) Chan C. C. and Chau K. T., *Modern Electric Vehicle Technology,* OXFORD University Press, 2001.

5) James Larminie, John Lowry, *Electric Vehicle Technology Explained*, Wiley 2003.
6) Fuhs A. E., *Hybrid Vehicles and the Future of Personal Transportation,* CRC Press, 2009.
7) Chris Mi , Abul Masrur M., *Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives,* Second Edition, John Wiley & Sons Ltd,2017.
8) Sheldon S. Williamson, *Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles*, Springer, 2013.

v) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction to Electric and Hybrid Electric Vehicles**: Hybrid and Electric Vehicles Components, Power transmission path, Social and environmental impacts of Electric and Hybrid vehicles. **Basics of Vehicle Performance:** Dynamic equation, Maximum tractive effort, Vehicle Power Plant and Transmission characteristics, vehicle performance factors. **Hybrid Electric Drive-trains:** Architecture of Hybrid Electric Drive Trains, various topologies, Power flow control in Series and Parallel Hybrid Electric Drive Trains.	9
II	**Electric propulsion:** Electric components used in electric and hybrid drives, Classification of Electric Motors in EV, Configuration and control of Drives -DC motor drives and Induction motor drives for Electric Vehicles	9
III	**Energy Storage for EV and HEV:** Energy storage requirements, Battery parameters, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices.	9
IV	**Sizing of Electric and Hybrid Electric Vehicles:** Sizing of major components - Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology.	9
V	**Communications and Energy Management strategies**: Introduction to CAN and Energy Management Strategies used in Electric and Hybrid Vehicles. **EV Charging Technologies:** Standards, Conductive and Inductive charging methods, Concept of V2G, G2V, V2B, V2V. **EV Charging infrastructure:** Policy, Impacts of integration of EVs in Smart Grid.	9
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE165A	PROCESS CONTROL AND INDUSTRIAL AUTOMATION	IEC	3	0	0	3	2022

i) COURSE OBJECTIVES

The course aims to introduce the concepts of process control and automation. It presents modelling and analysis of physical systems in time domain. Students will be introduced to classical controllers and advanced control strategies used in process control and concepts of process identification. Concepts of different automation components like actuators, control valves and PLCs will be discussed. The concepts of SCADA, Distributed Control Systems and safety cycle will also be introduced.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Model physical systems using time domain techniques	Apply
CO 2	Apply the concepts of classical and advanced control strategies in process control systems.	Apply
CO 3	Demonstrate the architecture and components of Industrial Automation Systems.	Understand
CO 4	Develop basic ladder programs for industrial automation applications.	Apply
CO 5	Explain the concepts of SCADA, DCS and Safety cycle	Understand

iii) SYLLABUS

Process control principles - Process control block diagram – Response analysis of first order and second order systems - Linearization - Transportation lag.

Study of On-off, P, PI and PID Controllers – Ziegler Nichol's tuning methods - Advanced control strategies - Digital Controllers - Process Identification.

Automation architecture - Actuators - Control Valves - Discrete state process control - Programmable Logic Controllers - Ladder programming – Concepts of SCADA, DCS – Safety Cycle.

iv) REFERENCES:

1) Coughanowr D. R., LeBlanc S., *Process Systems Analysis and Control*, 3rd Edition, McGraw-Hill, 2008.
2) C. D. Johnson, *Process Control Instrumentation Technology*, Pearson Education, Eighth Edition, 2006, PHI, 8th Edition, 2013.
3) William L. Luyben, *Process Modelling, Simulation and Control for Chemical Engineers*, Mc-Graw Hill, 2nd Edition, 2013.
4) Surekha Bhanot, *Process Control - Principles & Applications*, Oxford University Press, 2008.

5) Stephanopoulos G., *Chemical Process Control: An Introduction to Theory and Practice*, Pearson Education, PHI, 2006.
6) B. Wayne Bequette, *Process Control, Modeling, Design and Simulation*, Prentice Hall of India (P) Ltd., 2003.
7) Huges T, *Programmable Controllers*, ISA press, 4th Edition Illustrated, 2005.
8) K. Krishnaswamy, *Process Control*, New Age International, 2007.
9) Patranabis D., *Principles of Process Control*, Tata McGraw Hill, 3rd Edition, 2011.
10) Pao C. Chau, *Process Control – A First Course with MATLAB*, Cambridge series in Chemical Engineering, 1st Edition, 2002.

v) COURSE PLAN

Module	Contents	No. of hours
I	Introductory concepts: Process Control principles – self regulated system, Human aided control, Automatic control, Process Control block diagram. Modelling & response analysis of physical systems: First order systems - Liquid level control, mixing process and heating process, Concept of linearization of system model Response of first order systems in series – Non-interacting and interacting systems for liquid level control. Modelling of transportation lag	9
II	Study of Controllers: Closed loop system - ON-OFF control, Classical controllers - P, PI and PID controllers, Ziegler Nichol's methods for PID tuning. Advanced Control Strategies: Cascade control, Feed-forward control, Ratio Control, Smith Predictor control, Selective control, Model Reference Adaptive Control.	9
III	Concepts of Model Predictive Control and Statistical Process Control. Digital controllers: Block diagram, Effect of sampling, Digital PID controller Process Identification: Direct methods – Time domain eyeball fitting of Step test data, Direct sine wave testing	9
IV	Automation: Architecture of Industrial Automation Systems, Final control operation – Actuators and Control elements. Actuators – Construction, Principle, Advantages and disadvantages of Hydraulic, Pneumatic and Electrical actuators. Control elements – Control Valves construction and principle, Types – quick opening, linear, equal percentage, Classification	9
V	Discrete state process control: Programmable Logic Controllers – architecture and operation, Comparison of PLC & PC, Relays and Ladder Logic, Ladder Programming – Basic symbols used, Realization of AND, OR logic, Concept of latching. Introduction to Timer/Counters-Simple ladder programs.	9

	Introduction to SCADA: SCADA Systems, SCADA Architecture - monolithic, distributed and network. Concepts of Distributed control systems – DCS Structure, Advantages and disadvantages Introduction to IEC 61511/61408 and the safety cycle.	
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE165D	EMBEDDED SYSTEMS AND REAL TIME APPLICATIONS	IEC	3	0	0	3	2022

i) COURSE OBJECTIVES

After the successful completion of this course, students will be able to evaluate the different open source development boards used for real time projects. They will be able to analyse the different concepts of real time operating system and program accordingly.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Demonstrate the concepts, architecture and working of different types of embedded processors available for real time applications.	Understand
CO 2	Construct embedded C program for serial port communication and time delay using timers/counters of 8051.	Apply
CO 3	Develop programs based on ARM processor.	Apply
CO 4	Explain the concepts of real time Operating system design.	Understand

iii) SYLLABUS

Embedded Systems: Design issues, Hard and soft real-time systems, 8051 microcontroller architecture, Assembly language programming of timers, serial communication, interrupts.

Embedded C programming of 8051 timers, serial communication, interrupts, interfacing keyboard, stepper motor, analog/digital and LCD.

TI MSP 430 microcontroller: Architecture and programming. Case study of 8/16/32 bit microcontroller (8051, PIC/MSP 430, AVR)

ARM processor: Fundamentals, Cortex M3 architecture, Instruction set, Thumb Instructions, memory mapping, Registers. Optimizing ARM assembly code.

Real time operating system: Round robin,Function queue scheduling architecture. Memory management, priority inversion, thread synchronization

iv) REFERENCES:

1) Muhammed Ali Mazidi, *The 8051 Microcontroller and Embedded Systems Using Assembly and C*, 2nd Edition, Pearson India,2007.
2) David E Simon, *An Embedded Software Primer*,First Edition, Pearson Addison Wesley, 2002.

3) Raj Kamal , *Embedded Systems: Architecture, Programming and Design*, 3rd Edition, Tata McGraw Hill Education Pvt Ltd,2017.
4) Andrew Dominic & Chris, *Arm system developer's guide*: *Designing and Optimizing System Software*,first Edition, MK publishers,2004.
5) C.M. Krishna, Kang G. Shin, *Real-Time Systems*, first Edition, Tata Mc Graw Hill, 1997.
6) K.V.K.K.Prasad *Embedded Real-Time Systems: Concepts, Design & Programming*, second Edition,Dream Tech Press, 2005.

v) COURSE PLAN

Module	Contents	No. of hours
I	**Embedded Systems:** Definition and characteristics, Recent trends and challenges, Design issues, Hard and soft real time systems, 8051 microcontroller architecture, memory management, Addressing modes, Assembly language programming of timers, serial communication, interrupts. Bluetooth, Zig-Bee, GPS, Wi-Fi, Wi-Max based Communication	**9**
II	**Embedded C programming** of 8051 timers, serial communication, Interrupts, Interfacing - keyboard, stepper motor, Analog/Digital and LCD. PWM signal Generation, Co-ordinate transformations	**10**
III	TI MSP 430 microcontroller: Architecture and programming. Case study of 8/16/32 bit microcontroller (8051,PIC/MSP 430, AVR)	**8**
IV	**ARM processor:** Fundamentals, Cortex M3 architecture, Instruction set, Thumb Instructions, memory mapping, Registers. Optimizing ARM assembly code.	**10**
V	**Real time operating system:** Concepts, Round robin, round robin with interrupts, Function queue scheduling architecture, Semaphores, mutex, mailbox. Memory management, priority inversion, thread synchronization.	**8**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE165E	SMART GRID AND ENERGY STORAGE SYSTEMS	IEC	3	0	0	3	2022

i) COURSE OBJECTIVES

The course aims to provide students with a conceptual introduction to smart grids, its architecture, components and communication technologies. It also aims to provide an insight about the need for energy storage, devices and technologies available and their applications.

ii) COURSE OUTCOMES

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

CO 1	Illustrate the benefits and functions of Smart Grid and its various components.	Understand
CO 2	Explain the various Smart Grid Technologies.	Understand
CO 3	Illustrate the communication and computing technologies in Smart Grid.	Understand
CO 4	Choose suitable types of energy storage systems based on its characteristics	Apply
CO 5	Identify the functions of mobile and hybrid electrical storage systems	Apply

iii) SYLLABUS

Introduction to Smart Grids and Smart Grid Components Reference architecture – Smart meters – Wide Area Measurement System (WAMS), Phase Measurement Unit (PMU).

Smart Grid Technologies Smart Substations – IEC 61840 Substation Architecture, Smart Appliances.

Communication and Cloud Computing HAN, NAN, SANET – Communication Protocols – Cloud architecture of smart grid

Energy Storage Technologies Role of Energy storage Systems – Applications – Overview of energy storage technologies

Electrical energy storage Types – Characteristics and Specifications of Battery Storage – Mobile Energy Storage Systems – Hybrid Storage.

iv) REFERENCES

1) Ali Keyhani, Design of Smart Power Grid Renewable Energy Systems, Wiley-IEEE Press, 2011.
2) James Momoh, Smart Grid: Fundamentals of Design and Analysis, Wiley-IEEE Press, 2015.
3) Francisco Díaz-González, Andreas Sumper, Oriol Gomis-Bellmunt, Energy Storage in Power Systems. Wiley Publication, 2016.
4) Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, "Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals", Theory and Design, CRC Press, 2004.
5) Faisal M., Hannan M. A., Ker P. J., Hussain A., Mansor M. B., Blaabjerg F., "Review of Energy Storage System Technologies in Microgrid Applications: Issues and Challenges," in IEEE Access, vol. 6, pp. 35143-35164, 2018. doi: 10.1109/ACCESS.2018.2841407.
6) Yilmaz M., Krein P. T., "Review of Battery Charger Topologies, Charging Power Levels, and Infrastructure for Plug-In Electric and Hybrid Vehicles," IEEE Transactions on Power Electronics, vol. 28, no. 5, pp. 2151-2169, May 2013, doi: 10.1109/TPEL.2012.2212917.
7) Ma R., Chen H., Huang Y., Meng W., "Smart Grid Communication: Its Challenges and Opportunities," in IEEE Transactions on Smart Grid, vol. 4, no. 1, pp. 36-46, March 2013, doi: 10.1109/TSG.2012.2225851.

v) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction to Smart Grid**: Evolution of Electric Grid-Conventional Grid vs Smart Grid -Need and Definitions of Smart Grid-Benefits, Challenges and Key Application Areas of Smart Grid. **Smart Grid Components:** Smart Grid Reference Architecture-Introduction to Smart Meters, Real Time Pricing- Intelligent Electronic Devices (IED) and their application for monitoring & protection, Wide Area Measurement System (WAMS), Phase Measurement Unit (PMU)	9
II	**Smart Grid Technologies:** Smart Substations, Substation Automation, IEC 61840 Substation Architecture, Smart Appliances, Automatic Meter Reading(AMR), Advanced Metering Infrastructure (AMI) Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation.	9
III	**Communication Networks for Smart Grid**: Interoperability and connectivity - Home Area Network (HAN), Neighborhood-Area Networks (NANs), Sensor and Actuator Networks (SANETs)-Communication Protocols. **Cloud computing in Smart Grid**: Private, public and Hybrid cloud. Cloud architecture of smart grid.	9

IV	**Energy Storage Technologies**: Role of Energy storage Systems-Applications - Overview of energy storage technologies - Thermal, Mechanical, Chemical, Electrochemical, Electrical - Comparison of Various Storage Technologies-Criteria for Selection of Storage.	**9**
V	**Electrical Energy Storage**: Batteries, Super Capacitors, Superconducting Magnetic Energy Storage (SMES) - Principle of Operation-Advantages and Disadvantages. **Battery Energy Storage**: Characteristics – Technical Specifications - Need to avoid Overcharging, Charging Methodologies-Concept of Battery Management System. **Mobile Storage Systems**: Electric Vehicle, G2V, V2G. Basic concepts of Hybrid Energy storage systems.	**9**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1P62G	ELECTRICAL SYSTEM DESIGN AND BUILDING SERVICES	IEC	3	0	0	3	2022

i) COURSE OVERVIEW:

Goal of this course is to expose the students to the fundamental concepts of Electrical System Design for Buildings, the methodology of design, the Regulatory standards and essential building services. It introduces the students to the efficient use of Computer aided design with Ms Excel and use of software tools like AutoCAD for the preparation of Single Line Diagrams.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Explain the significance of Electricity Act 2003 and National Electric Code (NEC-2011) in the design of Electrical installations.	Understand
CO 2	Develop the Basis of Design (BOD) for a project as per the given floor layout.	Apply
CO 3	Analyse the design requirements of electrical installations in domestic buildings, high-rise buildings and substations.	Analyse
CO 4	Identify various components for Lightning protection in a building.	Apply

iii) SYLLABUS

Electrical System Design in Building Construction - The Indian Electricity Act 2003, National Electric Code (NEC 2011), National Building Code (NBC 2016)- Classification of voltages.

Design phase for electrical systems and develop the basis of design (BOD) for the project as per the given floor layout. Space requirements for a proper electrical installation as per NEC.

Design of electrical installations for domestic buildings - selection of main distribution board, sub distribution board, MCB, ELCB, MCCB - Electrical system layout designing.

Design requirements for high rise apartments and substation - Metering Panels - Cabling - Auxiliary and Emergency Power Supply.

Lightning protection system for a building – components - Code of practice for the protection of buildings.

iv) REFERENCES

1) Theodore R. Bosela, *Electrical Systems Design*, Prentice Hall; 1st Edition, 2002.
2) Giridharan M. K., *Electrical Systems Design*, I K International Publishers, New Delhi, 2nd Edition, 2016.
3) Aleksandar Mratinkovic & Co., *Design of Electrical Services for Buildings*, 3G E-Learning LLC, 2017.
4) Steven J. Marrano, ‘*Electrical System Design and Specification Handbook for Industrial Facilities*’, Fairmont Press, 1998
5) Jain V. K., Amitabh Bajaj, *Design of Electrical Installations*, Lakshmi Publications Pvt. Ltd.

6) Ruzhu Wang, Xiaoqiang Zhai, *Handbook of Energy Systems in Green Buildings*, Springer; 1st Edition, 2018.
7) Solanki C. S., *Solar Photovoltaic Technology and Systems: A Manual for Technicians, Trainers and Engineers*, Prentice Hall India Learning Private Limited ,2013.
8) *National Electric Code*, Bureau of Indian Standards publications, 2011.
9) Relevant Indian Standard – Specifications (IS – 732, IS – 746, IS – 3043, IS – 900), etc.

DATA BOOK (Approved for use in the examination):

1) Giridharan M. K., *Electrical Systems Design Data Hand book,* I K International Publishers, New Delhi, 2011.

v) COURSE PLAN

Module	Contents	No. of hours
I	Electrical System Design in Building Construction. Role of Statutes: The Indian Electricity Act 2003, National Electric Code (NEC 2011), National Building Code (NBC 2016), Classification of Building services – Major and Minor building services – Design aspects of building services, Classification of voltages, standards and specifications.	9
II	Design phase for electrical systems based on project size and develop the basis of design (BOD) for the project. Procedures of calculating and designing the electrical system based on Plot area, Floor Area Ratio (FAR), Load Power Density (LPD), Total Connected Load (TCL), Transformer and Generator Capacity. Need of MS Excel tool for efficient design methodology. Space requirements for electrical installation as per NEC	9
III	General aspects of the design of electrical installations for domestic dwellings as per NEC guidelines–connected load calculation, sub circuits, selection of main distribution board, sub distribution board, MCB, ELCB-selection of cables for sub circuit. Electrical drawings for the given project including floor plans and schematic diagrams. Practical Exercise – Design of electrical system of residential building using MS Excel	9
IV	Design requirements for high rise apartments- commercial and residential – Substations, Primary and Secondary protection, Earthing calculations - Metering Panels – Cabling – Auxiliary and Emergency Power Supply arrangements. Introduction to Solar PV installations and its statutory requirements.	9
V	Lightning protection system for a building and building services, Role of grounding in lightning protection systems, Main components of a lightning protection system, IS 2309 (2010): Code of practice for the protection of buildings and allied structures against lightning. NBC – IS / IEC 62305.	9
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE169B	ELECTRIC DRIVES AND SIMULATION LAB	LBC	0	0	2	1	2022

i) COURSE OBJECTIVES

The main objective of the course is to expose the students to the simulation software PSpice, simulate dc drives using MATLAB and hands-on session of drives.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Model rectifier circuits using PSpice	Apply
CO 2	Build rectifier control for DC drive using MATLAB	Apply
CO 3	Experiment with parallel inverters and choppers	Apply
CO 4	Compare the open loop control of DC and AC drives	Analyse

iii) LIST OF EXPERIMENTS

1) Simulation of Power Electronic Systems using PSpice
    a) Single phase uncontrolled half wave & Full wave rectifier
    b) Single phase half wave and Full wave controlled rectifier
2) Simulation of rectifier fed Electric Drives using Computer
    a) Single phase semi converter Fed separately excited DC motor
    b) Single phase Full converter Fed separately excited DC motor
    c) Three Phase Converter fed separately excited DC motor
3) Simulation of Chopper control Fed separately excited DC motor using Computer
4) Simulation of Electric Vehicle
5) Study of single phase parallel inverter.
6) Study of three phase parallel inverter
7) Open loop control of DC drive.
8) Open loop control of AC drive.
9) Jones chopper.
10) Simulation of Electric Vehicle

iv) REFERENCES

1) Rashid M H, *Power Electronics – Circuits, Devices and Applications*, Prentice Hall of India, New Delhi, 4th Edition, 2014.
2) Ned Mohan, Tore M. Undeland, William P.Robbins, *Power Electronics: Converters, Applications and Design*, 3rd Edition 2022.

3) Dubey G. K., *Power semiconductor control drives*, Prentice Hall, Englewood Cliffs, New Jersey, 1989.

v) COURSE PLAN

Expt. No.	Contents	No. of hours
1	Simulation of Power Electronic Systems using PSpice a) Single phase uncontrolled half wave & Full wave rectifier b) Single phase half wave & Full wave controlled rectifier	**3**
2	Simulation of rectifier fed Electric Drives using MATLAB a) Single phase semi converter Fed separately excited DC motor b) Single phase Full converter Fed separately excited DC motor c) Three Phase Converter fed separately excited DC motor	**3**
3	Simulation of Chopper control Fed separately excited DC motor using MATLAB a) Set-up the chopper fed dc drive using MATLAB b) Observe and Plot the waveforms for various duty cylces	**3**
4	Study of single-phase parallel inverter a) Set-up three phase parallel inverter b) Plot the trigger pulse and output waveforms	**3**
5	Study of three phase parallel inverter a) Set-up three phase parallel inverter b) Plot the trigger pulse and output waveforms	**4**
6	Open loop control of DC drive. a) Set-up Open loop control of DC drive b) Plot the trigger pulse and output waveforms	**4**
7	Open loop control of AC drive. a) Set-up Open loop control of DC drive b) Plot the trigger pulse and output waveforms	**4**
8	Jones chopper. a) Set-up Jones chopper circuit b) Plot the trigger pulse and output waveforms	**4**
9	Simulation of Electric Vehicle	**2**
	Total Hours	**30**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE167A	MINI PROJECT	PR	0	0	4	2	2022

i) COURSE OBJECTIVES

The goal of this course is to make students design and develop a system or application in the area of their specialization.

ii) APPROACH

The student shall present two seminars and submit a report. The first seminar shall highlight the topic, objectives, methodology, design and expected results. The second seminar is the presentation of the work / hardware implementation

iii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Solve real time problems faced by the society using the acquired knowledge within the chosen area of technology.	Create
CO 2	Compile report based on project related activities and findings.	Create
CO 3	Propose the results of the project comprehensively through presentation	Create

SEMESTER III SYLLABUS

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE178B	DISSERTATION PHASE I	PR	0	0	17	11	2022

i) COURSE OBJECTIVES

The goal of this course is to make students to:

1. Do independent study on the area of specialization.
2. Explore a subject in depth of his/her own choice.
3. Start the preliminary background studies towards the project by conducting literature survey in the relevant field.
4. Broadly identify the area of the project work, familiarize with the tools required for the design and analysis of the project.
5. Plan the experimental platform, if any, required for project work

ii) APPROACH

The student has to present two seminars and submit an interim Project report. The first seminar would highlight the topic, objectives, methodology and expected results. The first seminar shall be conducted in the first half of this semester. The second seminar is the presentation of the interim project report of the work completed and scope of the work which has to be accomplished in the fourth semester

iii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Identify literature for review and state research problems	Apply
CO 2	Analyse the acquired knowledge in the relevant area of study.	Analyse
CO 3	Identify research methods and the phases for scheduling work plan of the project work	Apply

SEMESTER IV SYLLABUS

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22EE178C	DISSERTATION PHASE II	PR	0	0	24	16	2022

i) COURSE OBJECTIVES

The goal of this course is to make students

1. Continue and complete the project work identified in Project (Phase I)

ii) APPROACH

There shall be two seminars (a mid-term evaluation on the progress of the work and pre submission seminar to assess the quality and quantum of the work). At least one technical paper has to be prepared for possible publication in journals / conferences based on their project work.

iii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Formulate research concepts clearly and communicate effectively.	Create
CO 2	Conclude the research in a coherent and convincing way by summarizing the key arguments and providing suitable findings.	Evaluate
CO 3	Compile the research work effectively for publication	Create
CO 4	Develop critical and innovative thinking to carry out future research activities	Create

{Subject to Approval by the competent Authorities}