DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

M.TECH
POWER ELECTRONICS & POWER SYSTEMS
COURSE STRUCTURE

(Applicable for batches admitted from 2025-2026)

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA

POWER ELECTRONICS & POWER SYSTEMS

COURSE STRUCTURE

I Year M. Tech I – Semester

S. No.	Course Title	L	T	P	C
1	**Program Core – 1** Power Electronic Converters	3	1	0	4
2	**Program Core – 2** Smart Grid Technologies	3	1	0	4
3	**Program Core – 3** Power System Operation & Control	3	1	0	4
4	**Program Elective – I** i. Electrical Machine Modelling and Analysis ii. Renewable Energy Technologies iii. HVDC Transmission and Flexible AC Transmission Systems	3	0	0	3
5	**Program Elective – II** i. Electrical Distribution Automation ii.Reactive Power Compensation and Management iii. Electric Vehicles	3	0	0	3
6	**Laboratory – 1** Power Systems Laboratory	0	1	2	2
7	**Laboratory – 2** Power Electronics Simulation Laboratory	0	1	2	2
8	Seminar-I	0	0	2	1
	TOTAL	**15**	**5**	**6**	**23**

I Year MTech II – Semester

S. No.	Course Title	L	T	P	C
1	**Program Core – 4** Power Electronic Control of Electrical Drives	3	1	0	4
2	**Program Core – 5** Switched Mode Power Conversion	3	1	0	4
3	**Program Core – 6** Real Time Control of Power Systems	3	1	0	4
4	**Program Elective – III** i.Advanced Digital Signal Processing ii. Applications of Power Converters iii. Industrial Internet of Things	3	0	0	3
5	**Program Elective – IV** i.Power Quality Enhancement using Custom Power Devices ii.Advanced Power Systems Protection iii. Battery Management Systems and Charging Stations	3	0	0	3
6	**Laboratory – 3** Power System Simulation Laboratory	0	1	2	2
7	**Laboratory – 4** Power Converters & Drives Laboratory	0	1	2	2
8	Seminar – II	0	0	2	1
	TOTAL	**15**	**5**	**6**	**23**

I Year MTech I – Semester

S. No.	Course Title	L	T	P	C
1	Research Methodology and IPR / *Swayam 12 week MOOC course – RM&IPR*	3	0	0	3
2	Summer Internship/ Industrial Training (8-10 weeks)*	-	-	-	3
3	Comprehensive Viva#	-	-	-	2
4	Dissertation Part – A$	-	-	20	10
	TOTAL	**3**	**-**	**20**	**18**

* Student attended during summer / year break and assessment will be done in 3rd Sem.
# Comprehensive viva can be conducted courses completed upto second sem.
$ Dissertation – Part A, internal assessment

II Year MTech II – Semester

Sl. No.	Course Title	L	T	P	C
1	Dissertation Part – B%	-	-	32	16
	TOTAL	**-**	**-**	**32**	**16**

% External Assessment

I Semester	POWER ELECTRONIC CONVERTERS (Program Core – 1)	L	T	P	C
		3	1	0	4

Pre-Requisite: Power Electronics.

Course Objectives:

- To understand the static and dynamic characteristics of power switching devices including MOSFET, IGBT, GTO, GaN devices, and their gate drive circuit requirements.
- To apply operational principles and control techniques of single-phase and three-phase fully controlled AC-DC converters, including power factor evaluation and harmonic analysis.
- To analyze various PWM inverter modulation schemes for single-phase and three-phase voltage and current source inverters, including sinusoidal, third harmonic, and space vector PWM. Analyze advanced PWM modulation techniques for multi-level inverters.
- To understand multilevel inverter topologies such as diode-clamped, cascaded H-bridge, and modular multilevel converters.

Course Outcomes:

- Understand the characteristics and switching behavior of modern power devices and corresponding gate driver circuits. Understand the operation of AC-DC converters, two-level inverters and various multilevel inverter configurations.
- Apply various control strategies to improve input power quality and perform harmonic reduction in AC-DC conversion systems.
- Analyze and compare different PWM techniques for two-level and multi-level inverters to reduce harmonics.

UNIT– I

Overview of Switching Devices

Power MOSFET, IGBT, GTO, GaN devices-static and dynamic characteristics, gate drive circuits for switching devices.

UNIT– II

AC-DC converters

Single phase fully controlled converters with RL load– Evaluation of input power factor and harmonic factor- Continuous and Discontinuous load current, Power factor improvements, Extinction angle control, symmetrical angle control, PWM control, Single-phase single stage boost power factor corrected rectifier.

Three Phase AC-DC Converters, fully controlled converters feeding RL load with continuous and discontinuous load current, Evaluation of input power factor and harmonic factor-three phase dual converters.

UNIT– III

PWM Inverters: Voltage control of single-phase inverters employing phase displacement Control, Bipolar PWM, Unipolar PWM. Three-phase Voltage source inverters: Six stepped VSI operation-Voltage Control of Three-Phase Inverters employing Sinusoidal PWM, Third Harmonic PWM, Space Vector Modulation- Comparison of PWM Techniques- Three phase current source inverters.

UNIT– IV

Multilevel Inverters:

Introduction, Multilevel Concept, Types of Multilevel Inverters, Diode-Clamped Multilevel Inverter, Principle of Operation, Features of Diode-Clamped Inverter, Improved Diode Clamped Inverter, Cascaded H-bridge Multilevel Inverter, Principle of Operation, Features of Cascaded H-bridge Inverter, Fault tolerant operation of CHB Inverter, Comparison of DCMLI & CHB, Modular multilevel converters, principle of operation.

UNIT– V

PWM Multilevel Inverters:

CHB Multilevel Inverter: Stair case modulation-SHE PWM- Phase shifted Multicarrier modulation-Level shifted PWM- Diode clamped Multilevel inverter: SHE PWM-Sinusoidal PWM- Space vector PWM-Capacitor voltage balancing.

Text Books

1. Power Electronics: Converters, Applications, and Design- Ned Mohan, Tore M. .Undeland, William P. Robbins, John Wiley& Sons, 2nd Edition, 2003
2. Power Electronics-Md.H.Rashid –Pearson Education Third Edition- First IndianReprint-2008.

Reference Books:

1. Power Electronics Semiconductor Switches – Ram Shaw, 1993. . Power Electronics Daniel W. Hart - McGraw-Hill, 2011.
2. Elements of Power Electronics – Philip T. Krein, Oxford University press, 2014.
3. Power Converter Circuits – William Shepherd & Li Zhang-Yes Dee CRC Press, 2004.

I Semester	SMART GRID TECHNOLOGIES (Program Core – 2)	L	T	P	C
		3	1	0	4

Pre-requisite: Basic knowledge on smart concept communication protocols, renewable energy systems and electronic circuits.

Course Objectives:

- To understand concept of smart grid and developments on smart grid.
- To understand smart grid technologies and application of smart grid concept in hybrid electric vehicles etc.
- To have knowledge on smart substations, feeder automation and application for monitoring and protection.
- To understand the Concepts of micro grid and applications
- To analyze the effects of power quality in smart grid and to understand latest developments in ICT for smart grid

Course Outcomes:

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

- Analyse the smart grid policies and its developments.
- Develop the concepts of smart grid technologies in hybrid electrical vehicles etc.
- Understand smart substations, feeder automation, GIS etc.
- Analyze micro grids and its applications.
- Analyze the effect of power quality in smart grid and to understand latest developments in ICT for smart grid.

UNIT – 1

Introduction to Smart Grid: Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid, Concept of Resilient &Self-Healing Grid, Present development & International policies on Smart Grid. Case study of Smart Grid.

UNIT – 2

Smart Grid Technologies: Part-1: Introduction to Smart Meters, Real Time Prizing, Smart Appliances, Automatic Meter Reading(AMR), Outage Management System(OMS), Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation, Phase Shifting Transformers.

UNIT – 3

Smart Grid Technologies: Part-2: Smart Substations, Substation Automation, Feeder Automation. Geographic Information System(GIS), Intelligent Electronic Devices(IED) & their application for monitoring & protection, Smart storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage, Phase Measurement Unit(PMU),Wide Area Measurement System(WAMS).

UNIT – 4

Micro grids: Concept of micro grid, need & applications of microgrid, formation of microgrid, Issues of interconnection, protection & control of microgrid.

UNIT – 5

Power Quality Management in Smart Grid: Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.

Text Books:

1. Ali Keyhani, Mohammad N. Marwali, Min Dai "Integration of Green and Renewable Energy in Electric Power Systems", Wiley
2. Clark W. Gellings, "The Smart Grid: Enabling Energy Efficiency and Demand Response", CRC Press

Reference Books:

1. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, AkihikoYokoyama, "Smart Grid: Technology and Applications", Wiley
2. Jean Claude Sabonnadière, NouredineHadjsaïd, "Smart Grids", Wiley Blackwell 19
3. Peter S. Fox Penner, "Smart Power: Climate Changes, the Smart Grid, and the Future of Electric Utilities", Island Press; 1 edition 8 Jun 2010
4. S. Chowdhury, S. P. Chowdhury, P. Crossley, "Microgrids and Active Distribution Networks." Institution of Engineering and Technology, 30 Jun 2009
5. Stuart Borlase, "Smart Grids (Power Engineering)", CRC Press.
6. Andres Carvallo, John Cooper, "The Advanced Smart Grid: Edge Power Driving Sustainability: 1", Artech House Publishers July 2011.

I Semester	POWER SYSTEM OPERATION & CONTROL (Program Core – 3)	L	T	P	C
		3	1	0	4

Pre-requisite: Knowledge on Power Generation Engineering, Power Transmission Engineering.

Course Objectives:

- To study the unit commitment problem for economic load dispatch.
- To study the load frequency control of single area and two area systems with and without control.
- To study the effect of generation with limited energy supply.
- To study the effectiveness of interchange evaluation in interconnected power systems.

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

- Determine the unit commitment problem for economic load dispatch.
- Get the knowledge of load frequency control of single area system with and without control.
- Get the knowledge of load frequency control of two area system with and without control.
- Know the effect of generation with limited energy supply.
- Determine the interchange evaluation in interconnected power systems.

UNIT – 1

Unit commitment problem and optimal power flow solution: Unit commitment: Constraints in UCP, UC solution methods. Priority list method, Dynamic programming Approach.
Optimal power flow: OPF without inequality constraints, inequality constraints on control variables and dependent variables.

UNIT – 2

Single area Load Frequency Control: Necessity of keeping frequency constant. Definition of control area, single area control, Block diagram representation of an isolated Power System, Steady State analysis, Dynamic response-Uncontrolled case. Proportional plus Integral control of single area and its block diagram representation, steady state response.

UNIT – 3

Two area Load Frequency Control: Block Diagram development of two-area system, uncontrolled case and controlled case, tie-line bias control, steady state representation. Optimal two-area LF control- performance Index and optimal parameter adjustment. Load frequency control and Economic dispatch control, Automatic generation control (AGC)

UNIT – 4

Generation with limited Energy supply: Take-or-pay fuel supply contract, composite generation production cost function. Solution by gradient search techniques, Hard limits and slack variables, Fuel scheduling by linear programming.

UNIT – 5

Interchange Evaluation and Power Pools Economy Interchange: Economy interchange Evaluation, Interchange Evaluation with unit commitment, Multiple Interchange transactions, Other types of Interchange, power pools, transmission effects and issues.

Text Books:

1. Power Generation, Operation and Control - by A.J.WoodandF.Wollenberg, Johnwiley& sons Inc. 1984.
2. Modern Power System Analysis - by I.J.Nagrath & D.P.Kothari, Tata McGraw-Hill Publishing Company ltd, 2nd edition.

Reference Books:

1. Power system operation and control PSR Murthy B.S publication.
2. Electrical Energy Systems Theory - by O.I.Elgerd, Tata McGraw-Hill Publishing Company Ltd, 2nd edition.
3. Reactive Power Control in Electric Systems - by TJE Miller, John Wiley & sons.

I Semester	ELECTRICAL MACHINE MODELLING AND ANALYSIS (PROGRAM ELECTIVE–I)	L	T	P	C
		3	0	0	3

Pre-requisite: Electric Circuits & Electrical Machines.

Course Objectives:

- To impart knowledge of fundamental modeling concepts and reference frame transformations for the analysis of induction, synchronous, and special machines.
- To provide proficiency in formulating mathematical and state-space models for various electrical machines using modern transformation and circuit analysis techniques.
- To enable critical analysis of machine performance in steady-state and transient conditions using various operational scenarios.

Course Outcomes:

At the end of the course, student will be able to

- Explain the fundamental modeling principles and reference frame transformations for DC, induction, synchronous, and special electrical machines.
- Develop mathematical and state-space models for various electrical machines using transformation and circuit equations.
- Analyze steady-state and transient machine performance under varying operational conditions.

UNIT– I

Basic Concepts of Modeling & DC Machine Modeling :

Basic two-pole D.C. machine **-** Primitive 2-axis machine – Voltage and Current relationship – Torque equation. Mathematical model of separately excited D.C. motor and D.C. Series motor in state variable form – Mathematical model of D.C. shunt motor and D.C. Compound motor in state variable form, Steady state analysis – Transient state analysis, Transfer function of the D.C. motor, Sudden application of inertia load.

UNIT– II

Reference Frame Theory & 3-phase Induction Motor dq model:

Linear transformation – Phase transformation (abc to αβ0) – Power equivalence, Active transformation (αβ0 to dq0), transformations in complex plane, Commonly used reference frames and transformation between reference frames, Circuit model of a 3 phase Induction motor – Flux linkage equation – dq transformation of flux linkages in the complex plane – voltage equations

UNIT– III

Modeling of 3-phase Induction motor in various reference frames

Voltage equation transformation to a synchronous reference frame, dq model of induction motor in the stator reference frame, rotor reference frame and arbitrary reference frame, power equation, electromagnetic torque equation, state space model in induction motor with flux linkages as variables and current-flux variables

UNIT– IV

Modeling of 3-phase Synchronous Motor

Synchronous machine inductances – Circuits model of a 3-phase synchronous motor – derivation of voltage equations in the rotor's dq0 reference frame electromagnetic torque – State space model with flux linkages as variables.

UNIT– V
Special Machines:
Modeling of Permanent Magnet Synchronous motor – Modeling of Brushless DC Motor, Modeling of Switch Reluctance Motors

Text Books

1. Generalized theory of Electrical Machines -Fifth edition, Khanna Publishers P. S. Bimbhra, 1985.
2. AC Motor control and electric vehicle applications – Kwang Hee Nam – CRC press, Taylor & Francis Group, 2010.
3. Analysis of Electric Machinery and Drive Systems, 3rd Edition-Wiley-IEEE Press- Paul Krause, Oleg Wasynczuk, Scott D. Sudhoff, Steven Pekarek, Junr 2013.

Reference Books:

1. Dynamic simulation of Electric machinery using MATLAB / Simulink –CheeMunOng- Prentice Hall, 2003.
2. Magneto electric devices transducers, transformers and machines-G. R. Slemon- Wiley in New York, London, 1966.
3. Electric Motor Drives - Modeling, Analysis& control -R.Krishnan- Pearson Publications.

I Semester	RENEWABLE ENERGY TECHNOLOGIES (PROGRAM ELECTIVE -I)	L	T	P	C
		3	0	0	3

Pre requisite: Power Electronics.

Course Objectives:

- To understand the fundamental principles of renewable energy sources, distributed generation, and economic aspects including electricity generation cost and management options.
- To apply operational principles and mathematical models of induction generators including self-excitation, speed, and voltage control for renewable power systems.
- To analyze key factors in wind and photovoltaic power plant design, including site evaluation, turbine classification, PV cell characteristics, and maximum power point tracking techniques.
- To explore fuel cell technologies, their performance modeling, practical implementation challenges, and integration considerations for sustainable energy conversion and storage.

Course Outcomes:

At the end of the course, student will be able to,

- Understanding of renewable energy fundamentals, distributed generation concepts, and the economic/environmental impact of renewable power systems.
- Apply knowledge of induction generator operation and controls to model and control renewable energy conversion systems effectively.
- Analyze wind and solar energy system components, including turbine types, PV cell models, and MPPT algorithms, to optimize system performance.
- Explore fuel cell technologies, hydrogen storage issues, and system integration strategies for advancing renewable energy utilization.

UNIT– 1

Introduction: Renewable Sources of Energy; Distributed Generation; Renewable Energy Economics - Calculation of Electricity Generation Costs; Demand-Side Management Options; Supply-Side Management Options; Control of renewable energy based power Systems

UNIT– 2

Induction Generators: Principles of Operation; Representation of Steady-State Operation; Power and Losses Generated - Self-Excited Induction Generator; Magnetizing Curves and Self-Excitation - Mathematical Description of the Self-Excitation Process; Interconnected and Stand-alone operation - Speed and Voltage Control.

UNIT– 3

Wind Power Plants: Site Selection; Evaluation of Wind Intensity; Topography; Purpose of the Energy Generation- General Classification of Wind Turbines; Rotor Turbines; Multiple-Blade Turbines; Drag Turbines; Lifting Turbines - Generators and Speed Control Used in Wind Power Energy; Analysis of Small wind energy conversion system.

UNIT– 4

Photovoltaic Power Plants: Solar Energy; Generation of Electricity by Photovoltaic Effect; Dependence of a PV Cell on Temperature and irradiance input-output Characteristics - Equivalent Models and Parameters for Photovoltaic Panels; MPPT schemes: P&O,INC, effect of partial shaded condition. Applications of Photovoltaic Solar Energy-Economical Analysis of Solar Energy

UNIT– 5

Fuel Cells: The Fuel Cell; Low- and High-Temperature Fuel Cells; Commercial and Manufacturing Issues - Constructional Features of Proton Exchange-Membrane Fuel Cells; Reformers; Electrolyzer Systems; Advantages and Disadvantages of Fuel Cells - Fuel Cell Equivalent Circuit; Practical Determination of the Equivalent Model Parameters; Aspects of Hydrogen for storage

Text Books:

1. Felix A. Farret, M. Godoy Simo` es, Integration of Alternative Sources of Energy, John Wiley & Sons, 2006.
2. Remus Teodorescu, Marco Liserre, Pedro Rodríguez, Grid Converters for Photovoltaic and Wind Power Systems, John Wiley & Sons, 2011.

Reference Books:

1. Gilbert M. Masters, Renewable and Efficient Electric Power Systems, John Wiley & Sons, 2004

I Semester	HVDC TRANSMISSION AND FLEXIBLE AC TRANSMISSION SYSTEMS (PROGRAM ELECTIVE -I)	L	T	P	C
		3	0	0	3

Pre-requisite: Knowledge on Power Electronics, Power Systems and High Voltage Engineering

Course Objectives:

- To understand the fundamentals, components, and evolution of HVDC transmission systems, their advantages over HVAC, and basic FACTS concepts.
- To apply analysis techniques for HVDC converters including Graetz circuits, conduction modes, voltage waveforms, and converter control methods.
- To analyze control strategies for DC links, harmonic generation and filtering, as well as the operation and control of static shunt and series compensators in FACTS devices.
- To analyze the performance and control of advanced FACTS devices like STATCOM, SSSC, and Unified Power Flow Controllers for improving system stability and reactive power compensation.

Course Outcomes:

At the end of the course, student will be able to,

- Understanding of HVDC system components, types of DC links, and the basics of FACTS controllers and transmission system interconnections.
- Apply knowledge of HVDC converter configurations, firing angle control, and harmonic filter design to enhance power quality and control.
- Analyze DC link control schemes, harmonic effects, and the operational characteristics of shunt and series static compensators in power systems.
- Analyze the design, operation, and control of FACTS devices including DVR, STATCOM, and UPFC to optimize power flow and voltage stability in electrical networks.

UNIT– 1

HVDC Transmission: DC Power Transmission: Need for power system interconnections, Evolution of AC and DC transmission systems, Comparison of HVDC and HVAC Transmission systems, Types of DC links, relative merits, Components of a HVDC system, Modern trends in DC Transmission systems.

UNIT– 2

Analysis of HVDC Converters: Pulse number, choice of converter configurations, Analysis of Graetz circuit with and without overlap, voltage waveforms, Analysis of two and three valve conduction mode, Converter Bridge characteristics, Inverter mode of operation, voltage waveforms.

UNIT– 3

HVDC Control: Principles of DC link control, Converter Control characteristics, Control hierarchy Constant current Control, CEA Control, firing angle control of valves, starting and stopping of a dc link, Power control.AC-DC power flow.

Harmonics and Filters: effects of Harmonics, sources of harmonic generation, Types of filters – Design examples.

UNIT– 4

Flexible AC Transmission Systems (FACTS): FACTS concepts and general system conditions: Power flow in AC systems, Relative importance of controllable parameters, Basic types of FACTS controllers, shunt and series controllers, Current source and Voltage source converters.

UNIT– 5

Static Shunt Compensators: Objectives of shunt compensation, Methods of controllable VAR generation, Static Var Compensator, its characteristics, TCR, TSC, STATCOM, basic operating principle, control approaches and characteristics

Static Series Compensators: Objectives of series compensator, variable impedance type of series compensators, TCSC, TSSC-operating principles and control schemes, SSSC, Power Angle characteristics, Control range and VAR rating, Capability to provide reactive power compensation, external control

Introduction to Unified Power Flow Controller, Basic operating principles, Conventional control capabilities, Independent control of real and reactive power.

Text Books:

1. NarainG.Honorani, Laszlo Gyugyi: Understanding FACTS –Concepts and Technology of Flexible AC Transmission Systems, Wiley-IEEE Press, 2000.
2. K.R.Padiyar: HVDC Power Transmission Systems –Technology and System Interactions, New Age International Publishers, 2011.

Reference Books:

1. Kimbark: Direct Current Transmission, 1971.
2. Jos Arrillaga: High Voltage Direct Current Transmission, The Institution of electrical Engineers, 1998.
3. Yong Hua Song, Allan T Johns: Flexible AC Transmission Systems, The Institution of electrical Engineers, 1999.

I Semester	ELECTRICAL DISTRIBUTION AUTOMATION (PROGRAM ELECTIVE–II)	L	T	P	C
		3	0	0	3

Pre-requisite: Knowledge on basics of distribution systems, Compensation in electrical distribution systems, Circuit Analysis, concept of load modelling.

Course Objectives:

- To learn the importance of economic distribution of electrical energy.
- To analyse the distribution networks for V-drops, P_{Loss}calculations and reactive power.
- To understand the co-ordination of protection devices.
- To impart knowledge of capacitive compensation and voltage control.
- To understand the concepts of distribution automation.

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

- Analyse the distribution system concepts.
- Design the distribution system feeders and sub-stations.
- Analyse the distribution system protection and its coordination.
- Evaluate the capacitive compensation and voltage control.
- Understand the functions of distribution automation.

UNIT – 1

General : Introduction to Distribution systems, an overview of the role of computers in distribution system planning-Load modelling and characteristics - definition of basic terms like demand factor, utilization factor, load factor, plant factor, diversity factor, coincidence factor, contribution factor and loss factor-Relationship between the load factor and loss factor - Classification of loads (Residential, Commercial, Agricultural and Industrial) and their characteristics.

UNIT – 2

Distribution Feeders and Substations: Design consideration of Distribution feeders: Radial and loop types of primary feeders, voltage levels, and feeder-loading. Design practice of the secondary distribution system.

Location of Substations, Rating of a Distribution Substation, service area with 'n' primary feeders. Benefits derived through optimal location of substations.

UNIT – 3

Protective devices and coordination: Objectives of distribution system protection, types of common faults and procedure for fault calculation. Protective Devices: Principle of operation of fuses, circuit reclosers, line sectionalizer and circuit breakers.

Coordination of protective devices: General coordination procedure; types of coordination.

UNIT – 4

Capacitive compensation and Voltage control: Different types of power capacitors, shunt and series capacitors, effect of shunt capacitors (Fixed and switched), power factor correction, capacitor location. Economic justification. Procedure to determine the best capacitor location.

Voltage control: Equipment for voltage control, effect of series capacitors, effect of AVB/AVR, line drop compensation.

UNIT – 5

Distribution automation functions: Electrical system automation, EMS functional scope, DMS functional scope functionality of DMS- Steady state and dynamic performance improvement; Geographic information systems- AM/FM functions and Database management; communication options, supervisory control and data acquisition: SCADA functions and system architecture; Synchrophasors and its application in power systems.

Text Books:

1. "Electric Power Distribution System Engineering" by Turan Gonen, McGraw-Hill Book Company, 1986.
2. Distribution System Analysis and Automation, by Juan M. Gers, The Institution of Engineering and Technology, UK 2014.

Reference Books:

1. Electric Power Distribution-by A.S.Pabla, Tata McGraw-Hill Publishing Company, 4th edition, 1997.
Electrical Distribution V.Kamaraju –Mc Graw Hill
2. Handbook of Electrical Power Distribution – Gorti Ramamurthy-Universities press

I Semester	REACTIVE POWER COMPENSATION AND MANAGEMENT (PROGRAM ELECTIVE–II)	L	T	P	C
		3	0	0	3

Pre-requisite: Concepts of power systems.

Course Objectives:

- To study objectives and specifications of Load Compensation
- To analyse the steady state and transient state Characteristic of Line Compensation
- To develop skills in reactive power coordination
- To apply Reactive power management on the distribution side and user side
- To investigate reactive power control in electric traction systems and arc furnaces

Course Outcomes:

At the end of the course, student will be able to

- Learn and describe various load compensations.
- Determine the reactive power compensation in transmission lines.
- Demonstrate the mathematical model of reactive power compensating devices.
- Compare the distribution side and user side reactive power management.
- Get application of reactive power compensation in electrical traction & arc furnaces.

UNIT– 1

Load Compensation: Objectives and specifications – reactive power characteristics – inductive and capacitive approximate biasing – Load compensator as a voltage regulator – phase balancing and power factor correction of unsymmetrical loads- examples.

UNIT– 2

Line compensation: Steady state -Uncompensated line – types of compensation – Passive shunt and series and dynamic shunt compensation – examples.
Transient state - Characteristic time periods – passive shunt compensation – static compensations- series capacitor compensation –compensation using synchronous condensers – examples.

UNIT– 3

Reactive power coordination: Objective – Mathematical modelling – Operation planning – transmission benefits – Basic concepts of quality of power supply – disturbances- steady –state variations – effects of under voltages – frequency – Harmonics, radio frequency and electromagnetic interferences.

UNIT– 4

Distribution side Reactive power Management:
System losses –loss reduction methods – examples – Reactive power planning – objectives – Economics Planning capacitor placement – retrofitting of capacitor banks.
User side reactive power management:
KVAR requirements for domestic appliances – Purpose of using capacitors – selection of capacitors – deciding factors – types of available capacitor, characteristics and Limitations.

UNIT– 5

Reactive power management in electric traction systems and arc furnaces: Typical layout of traction systems – reactive power control requirements – distribution transformers- Electric arc furnaces – basic operations- furnaces transformer –filter requirements – remedial measures –power factor of an arc furnace.

Text Books:

1. Reactive power control in Electric power systems by T.J.E.Miller, John Wiley and sons, 1982 .
2. Reactive power Management by D.M.Tagare, Tata McGraw Hill, 2004

I Semester	ELECTRIC VEHICLES (PROGRAM ELECTIVE–II)	L	T	P	C
		3	0	0	3

Pre-requisite: Knowledge of Power Electronics and Electric Drives

Course Objectives:

- To understand the fundamental components of conventional vehicles, propulsion loads, drive cycles, and terrains along with concepts of electric and hybrid vehicles.
- To apply hybridization techniques in automobiles, including the design and comparison of HEV, PHEV, and fuel cell vehicles.
- To analyze motor control strategies, power electronic converters, and regenerative braking systems used in electric and hybrid electric vehicles.
- To analyze different energy storage systems such as batteries, ultra-capacitors, flywheels, and other advanced technologies for their suitability in electric and hybrid vehicles.

Course Outcomes:

At the end of the course, student will be able to,

- Understand the key components of conventional vehicles and contrast them effectively with electric and hybrid vehicles.
- Apply knowledge of hybrid vehicle architectures, motor control startegies and energy management systems to design or select appropriate ev's.
- Analyze the functionality of motor controllers, power electronic devices, and regenerative braking to optimize electric vehicle performance.
- Analyze various energy storage technologies and their integration into electric and hybrid vehicles to improve overall system efficiency.

UNIT– 1

Introduction:

Fundamentals of vehicle, components of conventional vehicle and propulsion load; Drive cycles and drive terrain; Concept and classification of electric vehicle and hybrid electric vehicle; History of electric and hybrid vehicles, Comparison of conventional vehicle with electric and hybrid vehicles.

UNIT– 2

Hybridization of Automobile:

Fundamentals of vehicle, components of conventional vehicle and propulsion load; Drive cycles and drive terrain; Concept of electric vehicle and hybrid electric vehicle; Plug-in hybrid vehicle, constituents of PHEV, comparison of HEV and PHEV; Fuel Cell vehicles and its constituents.

UNIT– 3

Motor Control in Electric Vehicles:

Role of motors in Electric Vehicles, factors to choose motors for EV, Comparison of motors for EV power train, Motor Controller Unit (MCU)- need and components, Motor control units of two- and four –wheel EVs, Regenerative braking.

UNIT– 4

Power Electronics in HEVs:

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

UNIT– 5
Battery and Storage Systems
Energy Storage Parameters; Lead–Acid Batteries; Ultra capacitors; Flywheels - Superconducting Magnetic Storage System; Pumped Hydroelectric Energy Storage; Compressed Air Energy Storage - Storage Heat; Energy Storage as an Economic Resource

Text Books

1. Ali Emadi, Advanced Electric Drive Vehicles, CRC Press, 2014.
2. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.

Reference Books:

1. MehrdadEhsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.
2. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.
3. H. Partab: Modern Electric Traction – Dhanpat Rai & Co, 2007.

Research Books:

1. Pistooa G., "Power Sources , Models, Sustanability, Infrastructure and the market", Elsevier 2008.
2. Mi Chris, Masrur A., and Gao D.W., " Hybrid Electric Vehicle: Principles and Applications with Practical Perspectives" 1995.

I Semester	POWER SYSTEMS LABORATORY (LABORATORY – 1)	L	T	P	C
		0	1	2	2

Pre-requisite: Power Systems and Power System Analysis.

Course Objectives:

- Understand and analyze the sequence impedances of alternators and transformers through various experimental methods such as direct measurement and fault analysis.
- Explore the performance characteristics of synchronous machines, including power-angle characteristics of salient pole machines.
- Gain hands-on experience in transformer connections, phase displacement, and equivalent circuit determination, enhancing understanding of transformer operations.
- Study the behaviour and parameters of transmission lines, including ABCD parameter measurement and performance analysis under different compensation conditions.
- Investigate phenomena related to long transmission lines, such as the Ferranti effect and line compensation techniques, to understand voltage regulation and power flow stability.

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

- Calculate the sequence impedances of the synchronous machine.
- Calculate the sequence impedances and explain the connections of the transformer.
- Describe the Ferranti effect and compensation in transmission lines.
- Analyze the performance and importance of transmission line parameters.
- Analyze the operation of various protection relays.

List of Experiments:

1. Determination of Sequence Impendence of an Alternator by direct method.
2. Determination of Sequence impedance of an Alternator by fault Analysis.
3. Measurement of sequence impedance of a three phase transformer
   (a) by application of sequence voltage. (b) using fault analysis.
4. Power angle characteristics of a salient pole Synchronous Machine.
5. Poly-phase connection on three single phase transformers and measurement of phase displacement.
6. Determination of equivalent circuit of 3-winding Transformer.
7. Measurement of ABCD parameters on transmission line model.
8. Performance of long transmission line without compensation.
9. Study of Ferranti effect in long transmission line.
10. Performance of long transmission line with shunt compensation.

I Semester	POWER ELECTRONICS SIMULATION LABORATORY (LABORATORY – 2)	L	T	P	C
		0	1	2	2

Course Objectives:

- To understand the switching characteristics and operational principles of power MOSFETs and IGBTs including their structural differences and performance parameters.
- To apply driver circuit design concepts for power MOSFET and IGBT to enable effective gate control and switching operations.
- To analyze the simulation results of various power converter topologies such as three-phase full converters, dual converters, and PWM-based inverters to understand waveforms and conduction modes.
- To evaluate different PWM techniques including unipolar, bipolar, space vector, third harmonic injection, and multilevel inverter modulation schemes for improving inverter output quality.

Course Outcomes:

At the end of the course, student will be able to,

- Understanding of power MOSFET and IGBT switching behavior, including their advantages and limitations in power electronic applications (Level 2).
- Capable of applying driver circuit designs for effective control of MOSFET and IGBT power devices in switching converters (Level 3).
- Analyze the performance of simulated converter and inverter circuits under various load conditions and modulation schemes for improved power electronic system design.
- Analyze multilevel inverter configurations through simulation to improve power quality and system performance in advanced applications.

Any 10 of the following experiments are to be conducted.

List of Experiments:

1. Illustrate the switching characteristics of power MOSFET and power IGBT
2. Illustrate the use of Driver circuit for power MOSFET and power IGBT
3. Simulation of three phase full converter with RL & RLE loads.
4. Simulation of three-phase dual converter.
5. Simulation of single-phase full bridge inverter using unipolar & bipolar PWM techniques.
6. Simulation of three-phase two-level inverter for 120º & 180º mode of conduction.
7. Simulation of three phase two-level inverter using SPWM.
8. Simulation of three phase two-level inverter using Third Harmonic PWM,
9. Simulation of three phase two-level inverter using space vector PWM.
10. Simulation of three phase three-level NPC inverter using SPWM
11. Simulation of three phase five-level diode clamped inverter using SPWM
12. Simulation of Stair case modulation and SHE PWM for single-phase seven-level cascaded H-bridge inverter.
13. Simulation of Multicarrier PWM techniques for three-phase five-level cascaded H-bridge inverter.
14. Simulation of Modular Multilevel Converter.

I Semester	SEMINAR - I	L	T	P	C
		0	0	2	1

II-Semester	POWER ELECTRONIC CONTROL OF ELECTRICAL DRIVES (PROGRAM CORE – 4)	L	T	P	C
		3	1	0	4

Pre-requisite: Knowledge of Power Electronics and Electrical Machines.

Course Educational Objectives:

- To understand the principles and working of different control methods for induction motor drives including V/f control, vector control, and direct torque control techniques.
- To apply sensorless control methods and state observers such as MRAS and Kalman filters to estimate motor parameters without speed sensors in induction motor drives.
- To analyze the control strategies and performance trade-offs of Permanent Magnet Synchronous Machines, Brushless DC motors, and Switched Reluctance Motors for efficient torque and speed control.

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

- Explain the concepts of vector control, sensorless speed estimation, DTC, and their significance in the operation of induction motor and permanent magnet motor drives.
- Demonstrate the implementation of rotor and stator field-oriented control and adapt sensorless control algorithms for real-time motor speed and torque control.
- Compare and analyze different motor control schemes including direct torque control and vector control techniques based on steady-state accuracy and dynamic response.
- Analyze the effectiveness of control strategies for the performance evaluation of Permanent Magnet Synchronous Machines, Brushless DC motors, and Switched Reluctance Motors for efficient torque and speed control.

UNIT– 1
Vector Control of Induction Motor Drive:
Open loop and closed loop V/f control, Principle of vector control – direct and indirect vector control, implementation of direct and indirect vector control, rotor field-oriented control, implementation of rotor field-oriented control, stator field-oriented control, field weakening control of induction motor.

UNIT– 2
Sensor less Control of induction Motor Drive:
Advantages of speed sensor less control, voltage current based speed sensor less control, MRAS-model reference adaptive systems, state equation of an induction motor, state observers, full-order observer, reduced order observer, Extended Kalman filter observers.

UNIT– 3
Direct Torque Control of Induction Motor Drive:
Principle of Direct torque control (DTC), concept of space vectors, DTC control strategy of induction motor, comparison between vector control and DTC, modified DTC of induction motor with constant switching frequency, space vector modulation based DTC of induction motors.

UNIT– 4
Control of Permanent Magnet Synchronous Machines (PMSM) and Brushless DC (BLDC) Motor Drives:
Advantages and limitations of Permanent magnet machines, operating principle of PMSM, vector control for PMSM, operating principle of BLDC, modeling of BLDC, similarities and difference between PMSM and BLDC, need for position sensing in BLDC motors, control strategies for PMSM and BLDC, methods of reducing torque ripples of BLDC motor.

UNIT– 5
Control of Switched Reluctance Motor (SRM) Drive:
SRM structure, Merits and limitations, stator excitation, converter topologies, SRM waveforms, Torque control schemes, speed control of SRM, torque ripple minimization, instantaneous -torque control using current controllers and flux controllers.

Text Books:

1. Bose B. K., "Power Electronics and Variable Frequency Drives', IEEE Press, Standard Publisher Distributors. 2001.
2. Kwang Hee Nam, "AC Motor Control and Electrical Vehicle Applications" Second Edition, CRC Press.

Reference Books:

1. Seung-Ki Sul, "Control of Electric Machine Drive Systems" IEEE Press, A John Wiley & Sons, Inc. Publications. 2011.
2. Krishnan R., "Electric Motor Drives – Modeling, Analysis and Control", Prentice Hall of India Private Limited.
3. Switched Reluctance Motors and Their Control-T. J. E. Miller, Magna Physics, 1993.
4. Power electronic converters applications and design-Mohan, Undeland, Robbins-Wiley publications.

II-Semester	SWITCHED MODE POWER CONVERSION (PROGRAM CORE – 5)	L	T	P	C
		3	1	0	4

Pre-requisite: Concepts of electrical circuit analysis and power electronics.

Course Educational Objectives:

- To understand the fundamental principles, topologies, and operating modes of non-isolated, isolated, and resonant power converters, including essential design considerations for components and control.
- To apply appropriate modeling techniques and analytical methods to design, simulate, and implement dc-dc converter circuits and their control systems.
- To analyze and interpret the effects of non-ideal components, magnetic and thermal considerations, and control strategies on the performance of power converters.

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

- Explain the operation of non-isolated, isolated, and resonant DC-DC converters.
- Design power converter circuits with appropriate selection of components, magnetic designs, and control techniques.
- Develop averaged large signal, steady state and small signal mathematical models for controller design

UNIT– 1
Non-isolated switch mode converters:
Control of DC-DC converters: Buck converters, Boost converters, Buck-Boost converter, CUK Converter, continuous and discontinuous operation, Converter realization with non-ideal components.

UNIT– 2
Isolated switched mode converters:
Forwarded converter, flyback converter, push-pull converter, half-bridge converter, full bridge converter.

UNIT– 3
Resonant converters:
Basic resonant circuit concepts, series resonant circuits, parallel resonant circuits, zero current switching quasi-resonant buck converter, zero current switching quasi-resonant boost converter, zero voltage switching quasi-resonant buck converter, zero voltage switching quasi-resonant boost converter, load resonant converter.

UNIT– 4
Design of Power Converters Components: Magnetic concepts - design of inductor, design of transformer, Selection of filter capacitors, Selection of ratings for devices, input filter design, Thermal design

UNIT– 5
Modeling and Controller design:
Circuit averaging method and average switch model technique to obtain averaged large signal model, steady state model, small signal models of buck, boost, buck-boost converters, Derivation of converter transfer functions for buck, boost and buck-boost topologies. Voltage mode control, Current mode control, current mode control instability, slope compensation, Controller design using Bode approach.

Text Books:

1. Fundamentals of Power Electronics-Erickson, Robert W., Maksimovic, Dragan, Springer, 2011.
2. Power switching converters-Simon Ang, .Alejandro Oliva, CRC Press, 2010
3. Power Electronics: Essentials and applications- L. Umanand, Wiley publications

Reference Books:

1. Design of Magnetic Components for Switched Mode Power Converters- Umanand, S.P. .Bhat, John Wiley & Sons Australia, 1992
2. Switching Power Supply Design-Abraham I. Pressman, McGraw-Hill Ryerson, Limited, 1991.
3. Power Electronics – IssaBatareseh, Jhon Wiley publications, 2004.
4. Power Electronics: converters Applications & Design – Mohan, Undeland, Robbins-Wiley publications.

II-Semester	REAL TIME CONTROL OF POWER SYSTEMS (PROGRAM CORE – 6)	L	T	P	C
		3	1	0	4

Pre-requisite: Power system operation and control.

Course Objectives:

- Understand the principles of state estimation in power systems and the application of Weighted Least Squares (WLS) methods.
- Analyze system security and perform contingency evaluations using various techniques.
- Recognize the need for real-time monitoring and control of power systems and understand the SCADA system structure and functionality.
- Evaluate voltage stability and voltage collapse phenomena using analytical tools and indices.
- Understand the role and functionality of Phasor Measurement Units (PMUs) and their integration with communication systems and control centers.

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

- Explore different types of state estimation techniques and handle bad data in measurements and assess system observability.
- Analyze system security and perform contingency analysis for generator and line outages using iterative and fast decoupled power flow models.
- Understand and explain the operating states of power systems and the architecture and function of SCADA systems.
- Evaluate voltage stability using P-V and Q-V curves, and analyze long-term voltage stability and collapse scenarios.
- Demonstrate knowledge of PMU structure, phasor representation, GPS synchronization, and evaluate DFT estimation for off-nominal frequency signals.

UNIT – 1:

State Estimation: Different types of State Estimations, Theory of WLS state estimation, sequential and non-sequential methods to process measurements. Bad data Observability, Bad data detection, identification and elimination.

UNIT – 2:

Security and Contingency Evaluation : Security concept, Security Analysis and monitoring, Contingency Analysis for Generator and line outages by iterative linear power flow method, Fast Decoupled model, and network sensitivity methods.

UNIT – 3:

Computer Control of Power Systems: Need for real time and computer control of power systems, operating states of a power system, SCADA - Supervisory control and Data Acquisition systems implementation considerations, energy control centres, software requirements for implementing the above functions.

UNIT – 4:

Voltage Stability: Definitions of Voltage Stability, voltage collapse, and voltage security, relation of voltage stability to rotor angle stability. Voltage stability analysis Introduction to voltage stability analysis `P-V’ curves and `Q-V’ curves, voltage stability in mature power systems, long-term voltage stability, power flow analysis for voltage stability, voltage stability static indices.

UNIT – 5:

Synchro phasor Measurement units: Introduction, Phasor representation of sinusoids, a generic PMU, GPS, Phasor measurement systems, Communication options for PMUs, Functional requirements of PMUs and PDCs, Phasors for nominal frequency signals, types of frequency excursions in power systems, DFT estimation at off nominal frequency with a nominal frequency clock.

Text Books:

1. John J.Grainger and William D.Stevenson, Jr. : Power System Analysis, McGraw-Hill, 1994, International Edition
2. Allen J.Wood and Bruce F.Wollenberg : Power Generation operation andcontrol, John Wiley & Sons, 1984.
3. A.G.Phadka and J.S. Thorp, "Synchronized Phasor Measurements and Their Applications", Springer, 2008

Reference Books:

1. R.N.Dhar : Computer Aided Power Systems Operation and Analysis, Tata McGraw Hill, 1982
2. L.P.Singh : Advanced Power System Analysis and Dynamics, WileyEastern Ltd. 1986
3. PrabhaKundur : Power System Stability and Control -, McGraw Hill, 1994
4. P.D.Wasserman : `Neural Computing : Theory and Practice' Van Nostrand -Feinhold, New York.

II-Semester	ADVANCED DIGITAL SIGNAL PROCESSING (PROGRAM ELECTIVE – III)	L	T	P	C
		3	0	0	3

Pre-requisite: Signals & Systems

Course Educational Objectives:

- To understand fundamental digital signal processing concepts, including discrete signals, transforms, and filter structures.
- To apply design techniques for FIR and IIR digital filters using various methods like bilinear transform and windowing.
- To analyze the effects of finite word length, quantization errors, and implement DSP algorithms efficiently.
- To evaluate power spectrum estimation methods and optimize DSP filter implementations for computational complexity.

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

UNIT– 1
Digital Filter Structure: Block diagram representation-Equivalent Structures-FIR and IIR digital filter Structures All pass Filters-tunable IIR Digital Filters-IIR tapped cascaded Lattice Structures-FIR cascaded Lattice structures-Parallel-Digital Sine-cosine generator-Computational complexity of digital filter structures.

UNIT– 2
Digital filter design: Preliminary considerations-Bilinear transformation method of IIR filter design-design of lowpass, high pass-band pass, and band stop- IIR digital filters-Spectral transformations of IIR filters, FIR filter design-based on windowed Fourier series- design of FIR digital filters with least –mean- square-error-constrained least-square design of FIR digital filters

UNIT– 3
DSP algorithm implementation: Computation of the discrete Fourier transform- number representation-arithmetic operations handling of overflow-tunable digital filters-function approximation.

UNIT– 4
Analysis of finite Word length effects: The quantization process and errors- quantization of fixed -point and floating -point Numbers-Analysis of coefficient quantization effects, Analysis of arithmetic round-off errors, dynamic range scaling-signal- to- noise ratio in low -order IIR filters-low-sensitivity digital filters-Reduction of Product round-off errors using error feedback-Limit cycles in IIR digital filters, Round-off errors in FFT Algorithms.

UNIT– 5
Power Spectrum Estimation: Estimation of spectra from finite duration observations signals – Non-parametric methods for power spectrum estimation – parametric method for power spectrum estimation, estimation of spectral form-finite duration observation of signals-non-parametric methods for power spectrum estimation-Walsh methods-Blackman & torchy method.

Text Books:

1. Digital signal processing-Sanjit K. Mitra-TMH second edition, 2002.
2. Discrete Time Signal Processing – Alan V.Oppenheim, Ronald W.Shafer - PHI-1996 1st edition-9th reprint

Reference Books:

1. Digital Signal Processing and principles, algorithms and Applications – John G.Proakis - PHI –3rd edition-2002.
2. Digital Signal Processing – S.Salivahanan, A.Vallavaraj, C. Gnanapriya – TMH - 2nd reprint-2001
3. Theory and Applications of Digital Signal Proceesing-LourensR. Rebinar&Bernold.
4. Digital Filter Analysis and Design-Auntonian-TMH.

II-Semester	APPLICATIONS OF POWER CONVERTERS (PROGRAM ELECTIVE – III)	L	T	P	C
		3	0	0	3

Pre-requisites: Analysis of Power Electronic Converters

Course Educational Objectives:
- To understand inverter applications for induction heating and power conditioning systems.
- To analyze power converters for lighting, pumping, and refrigeration systems including PV-based drivers.
- To compare and contrast high voltage and low voltage high current power supplies for specialized industrial and computing loads.
- To develop and evaluate bi-directional DC-DC converters and active power filters for automotive and power quality applications.

Course Outcomes: At the end of the course, the student will be able to
- Describe the functioning and control of power electronic inverters and converters for various industrial applications.
- Analyze and interpret the performance of power supplies and converter circuits for lighting, HVAC, X-ray and space applications.
- Design power electronic converters including bidirectional DC-DC converters and power conditioners.
- Critically analyze power quality improvement techniques including active and hybrid power filters and UPS systems in practical scenarios.

UNIT-1
Inverters for Induction Heating: For induction cooking, induction hardening, melting, and welding applications.

UNIT-2
Power Converters for Lighting, pumping and refrigeration Systems: Electronic ballast, LED power drivers for indoor and outdoor applications. PFC based grid fed LED drivers, PV / battery fed LED drivers. PV fed power supplies for pumping/refrigeration applications.

UNIT-3
High Voltage Power Supplies - Power supplies for X-ray applications - power supplies for radar applications - power supplies for space applications.
Low voltage high current power supplies: Power converters for modern microprocessor and computer loads

UNIT-4
Bi-directional DC-DC (BDC) converters: Electric traction, automotive Electronics and charge/discharge applications, Line Conditioners and Solar Charge Controllers

UNIT-5
Power Conditioners:
Uniterupted Power Supplies - Active Power Filters - Shunt active power filters - Series active power filters - Hybrid active power filters - UPQC

Text Books:
1. Ali Emadi, A. Nasiri, and S. B. Bekiarov: Uninterruptible Power Supplies and Active Filters, CRC Press, 2005.

2. M. Ehsani, Y. Gao, E. G. Sebastien and A. Emadi: Modern Electric, Hybrid Electric and Fuel Cell Vehicles, 1st Edition,CRC Press, 2004.

References Books:

1. William Ribbens: Understanding Automotive Electronics, Newnes, 2003.

II-Semester	INDUSTRIAL INTERNET OF THINGS (PROGRAM ELECTIVE – III)	L	T	P	C
		3	0	0	3

Pre-requisites:

Course Objectives:
- To understand IoT architectures, protocols, and communication principles.
- To apply programming skills for IoT device integration using Arduino and Raspberry Pi.
- To analyze domestic and industrial appliance technologies and embedded IoT solutions.
- To evaluate cloud and edge computing approaches for IoT data management and smart applications.

Course Outcomes: At the end of the course, the student will be able to
- Explain IoT communication models and interoperability.
- Develop IoT applications with sensors and actuators integration.
- Investigate IoT-enabled devices and optimize power and control systems.
- Critically assess IoT data analytics, SDN, and AI/ML applications in IoT.
  Course Objectives:

UNIT-1
IoT Communication Technologies: Introduction to IoT, Sensing, Actuation, Basics of Networking, Communication Protocols, Sensor Networks, Machine-to-Machine Communications. Interoperability in IoT.

UNIT-2
IoT Control Technologies and Programming: Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino, Internet of Things Open-Source Systems. Introduction to Python programming, Introduction to Raspberry. Implementation of IoT with Raspberry Pi, Smart Grid Hardware Security.

UNIT-3
Domestic & Industrial Appliances (Part-1): Solid State Lamps: Introduction - Review of Light sources - white light generation techniques-Characterization of LEDs for illumination application. Power LEDs - High brightness LEDs - Electrical and optical properties. LED driver considerations- Power management topologies -color issues of white LEDs- Dimming of LED sources,

UNIT-4
Domestic & Industrial Appliances (Part-2): BLDC motors for pumping and domestic fan appliances, inverter technology-based home appliances, Smart devices and equipment. Industrial IoT applications Factories and Assembly Line- Power Plants, Plant Safety and Security (Including AR and VR safety applications)- Oil and chemical Industry- Applications of UAVs in Industries.

UNIT-5
IoT Cloud Computation and Applications: Introduction to SDN. SDN for IoT, Data Handling and Analytics, Cloud Computing, Sensor- Cloud. Fog Computing, Smart Cities and Smart Homes, Electric Vehicles, Industrial IoT, Case Study: Agriculture, Healthcare, Activity Monitoring, Role of ML and AI in IoT.

Text Books:

1. Sudip Misra, Chandana Roy, Anandarup Mukherjee, Introduction to Industrial Internet of Things and Industry 4.0, CRC press, 2021.
2. Kostas Siozios, Dimitrios Anagnostos, Dimitrios Soudris, Elias Kosmatopoulos, IoT for Smart Grids: Design Challenges and Paradigms, Springer publishers, 2019.

3. Vinod Kumar Khanna, Fundamentals of Solid-State Lighting: LEDs, OLEDs, and Their Applications in Illumination and Displays, CRC press, 2014, 1st Edition.

Reference Books:

1. Alasdair Gilchrist, Industry 4.0: The Industrial Internet of Things, Apress Publishers, 2016.
2. Craig Di Louie, Advanced Lighting Controls: Energy Savings, Productivity, Technology and Applications, River publishers, 2006, e-book, 2021,1st Edition.
3. Chang-liang Xia, Permanent Magnet Brushless DC Motor Drives and Controls, John Wiley & Sons Singapore Pte. Ltd., 2012, 1st Edition.

Other Suggested Readings:

https://nptel.ac.in/courses/106105166

II-Semester	POWER QUALITY ENHANCEMENT USING CUSTOM POWER DEVICES (PROGRAM ELECTIVE–IV)	L	T	P	C
		3	0	0	3

Pre requisite: Knowledge on electric circuit analysis, power systems and power electronics and concept of reactive power compensation techniques.

Course Educational Objectives:

- To understand significance of power quality and power quality parameters.
- To analyze types of transient over voltages and protection of transient voltages.
- To examine harmonics, their effects, harmonic indices and harmonic minimization techniques.
- To know the importance of power devices and their applications.
- To understand different compensation techniques to minimize power quality disturbances.

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

- Identify the issues related to power quality in power systems.
- Address the problems of transient and long duration voltage variations in power systems.
- Analyze the effects of harmonics and study of different mitigation techniques.
- Identify the importance of custom power devices and their applications.
- Acquire knowledge on different compensation techniques to minimize power quality disturbances.

UNIT– 1

Introduction to power quality: Overview of Power Quality, Concern about the Power Quality, General Classes of Power Quality Problems, Voltage Unbalance, Waveform Distortion, Voltage fluctuation, Power Frequency Variations, Power Quality Terms, Voltage Sags, swells, flicker and Interruptions - Sources of voltage and current interruptions, Nonlinear loads.

UNIT– 2

Transient and Long Duration Voltage Variations: Source of Transient Over Voltages - Principles of Over Voltage Protection, Devices for Over Voltage Protection, Utility Capacitor Switching Transients, Utility Lightning Protection, Load Switching Transient Problems.

Principles of Regulating the Voltage, Device for Voltage Regulation, Utility Voltage Regulator Application, Capacitor for Voltage Regulation, End-user Capacitor Application, Regulating Utility Voltage with Distributed generation

UNIT– 3

Harmonic Distortion and solutions: Voltage vs. Current Distortion, Harmonics vs. Transients - Power System Quantities under Non-sinusoidal Conditions, Harmonic Indices, Sources of harmonics, Locating Sources of Harmonics, System Response Characteristics, Effects of Harmonic Distortion, Inter harmonics, Harmonic Solutions Harmonic Distortion Evaluation, Devices for Controlling Harmonic Distortion, Harmonic Filter Design, Standards on Harmonics

UNIT– 4

Custom Power Devices: Custom power and custom power devices, voltage source inverters, reactive power and harmonic compensation devices, compensation of voltage interruptions and current

interruptions, static series and shunt compensators, compensation in distribution systems, interaction with distribution equipment, installation considerations.

UNIT– 5

Application of custom power devices in power systems: Static and hybrid Source Transfer Switches, Solid state current limiter - Solid state breaker. P-Q theory – Control of P and Q, Dynamic Voltage Restorer (DVR), Operation and control of Interline Power Flow Controller (IPFC), Operation and control of Unified Power Quality Conditioner (UPQC), Generalized power quality conditioner.

Text Books:

1. Electrical Power Systems Quality, Dugan R C, McGranaghan M F, Santoso S, and Beaty H W, Second Edition, McGraw-Hill, 2002.
2. Understanding Power Quality Problems: Voltage Sags and Interruptions, Bollen M H J, First Edition, IEEE Press; 2000.
3. Guidebook on Custom Power Devices, Technical Report, Published by EPRI, Nov 2000
4. Power Quality Enhancement Using Custom Power Devices – Power Electronics and Power Systems, Gerard Ledwich, ArindamGhosh, Kluwer Academic Publishers, 2002.

Reference Books:

1. Power Quality Primer, Kennedy B W, First Edition, McGraw-Hill, 2000.
2. Power System Harmonics, Arrillaga J and Watson N R, Second Edition, John Wiley & Sons, 2003.
3. Electric Power Quality control Techniques, W. E. Kazibwe and M. H. Sendaula, Van Nostrad Reinhold, New York.
4. Power Quality c.shankaran, CRC Press, 2001
5. Harmonics and Power Systems –Francisco C.DE LA Rosa-CRC Press (Taylor & Francis).
6. Power Quality in Power systems and Electrical Machines-EwaldF.fuchs, Mohammad A.S. Masoum-Elsevier
7. Power Quality, C. Shankaran, CRC Press, 2001
8. Instantaneous Power Theory and Application to Power Conditioning, H. Akagiet.al., IEEE Press, 2007.
9. Custom Power Devices - An Introduction, ArindamGhosh and Gerard Ledwich, Springer, 2002
10. A Review of Compensating Type Custom Power Devices for Power Quality Improvement, Yash Pal et.al., Joint International Conference on Power System Technology and IEEE Power India Conference, 2008. POWERCON 2008.

II-Semester	ADVANCED POWER SYSTEM PROTECTION (PROGRAM ELECTIVE–IV)	L	T	P	C
		3	0	0	3

Pre-requisite: Concepts of Power Electronics, Electronic circuits, STLD and basics of Relays and protection.

Course Objectives:
- To learn about classification and operation of static relays.
- To understand the basic principles and application of comparators.
- To learn about static version of different types of relays.
- To understand about microprocessor and numerical protection techniques.

Course Outcomes: At the end of the course, student will be able to
- Know the classifications and applications of static relays.
- Understand the application of comparators.
- Understand the static version of different types of relays.
- Understand the microprocessor and numerical protection techniques.

UNIT – 1
Static Relays classification and Tools: Comparison of Static with Electromagnetic Relays, Basic classification, Level detectors and Amplitude and phase Comparators – Duality – Basic Tools – Schmitt Trigger Circuit, Multivibrators, Square wave Generation – Polarity detector – Zero crossing detector – Thyristor and UJT Triggering Circuits. Phase sequence Filters – Speed and reliability of static relays.

UNIT – 2
Amplitude and Phase Comparators (2 Input) : Generalized equations for Amplitude and Phase comparison – Derivation of different characteristics of relays – Rectifier Bridge circulating and opposed voltage type amplitude comparators – Averaging & phase splitting type amplitude comparators – Principle of sampling comparators.
Phase Comparison : Block Spike and phase Splitting Techniques – Transistor Integrating type, phase comparison, Rectifier Bridge Type Comparison – Vector product devices.

UNIT – 3
Static over current (OC) relays – Instantaneous, Definite time, Inverse time OC Relays, static distance relays, static directional relays, static differential relays, measurement of sequence impedances in distance relays, multi input comparators, elliptic & hyperbolic characteristics, switched distance schemes, Impedance characteristics during Faults and Power Swings.

UNIT – 4
PILOT Relaying schemes: Wire pilot protection: circulating current scheme – balanced voltage scheme – translay scheme – half wave comparison scheme - carrier current protection: phase comparison type – carrier aided distance protection – operational comparison of transfer trip and blocking schemes – optical fibre channels.

UNIT – 5
Microprocessor based relays and Numerical Protection: Introduction – over current relays – impedance relay – directional relay – reactance relay.
Numerical Protection: Introduction - numerical relay - numerical relaying algorithms – mann-morrison technique - Differential equation technique and discrete fourier transform technique - numerical over current protection - numerical distance protection.

Text Books:
1. Power System Protection with Static Relays – by TSM Rao, TMH.
2. Power system protection & switchgear by Badri Ram & D N viswakarma, TMH.

Reference Books:
1. Protective Relaying Vol-II Warrington, Springer.
2. Art & Science of Protective Relaying - C R Mason, Willey.
3. Power System Stability Kimbark Vol-II, Willey.
4. Electrical Power System Protection –C.Christopoulos and A.Wright- Springer
5. Protection & Switchgear –Bhavesh Bhalaja, R.PMaheshwari, Nilesh G.Chothani-Oxford publisher

II-Semester	BATTERY MANAGEMENT SYSTEMS AND CHARGING STATIONS (PROGRAM ELECTIVE – IV)	L	T	P	C
		3	0	0	3

Pre-Requisite: Basic knowledge of electrochemistry, circuit theory, and electrical energy systems.

Course Objectives:

- To understand the fundamental types, characteristics, and chemistry of various EV batteries including lead-acid, nickel-based, sodium-based, and lithium-ion batteries.
- To apply diverse battery charging algorithms and balancing techniques to safely and efficiently manage battery pack charging under different operational conditions.
- To analyze the design and functional requirements of battery management systems, sensing and control elements, and the architecture of domestic and public EV charging infrastructure.
- To evaluate electrochemical battery models and simulation techniques to predict performance, state of charge, and optimize battery system design and operation.

Course Outcomes:

At the end of the course, student will be able to,

- Understanding of EV battery types, nominal ratings, and special characteristics relevant to electric vehicle applications.
- Apply appropriate charging algorithms and balancing strategies to improve battery life, safety, and efficiency across various battery chemistries.
- Analyze BMS components, communication protocols, and charging infrastructure configurations to design robust EV battery systems.
- Evaluate battery simulation models and diagnostic methods for enhancing EV battery performance and management strategies in practical scenarios.

Unit - I:

EV Batteries

Cells & Batteries, Nominal voltage and capacity, C rate, Energy and power, Cells connected in series, Cells connected in parallel. **Lead Acid Batteries:** Lead acid battery basics, special characteristics of lead acid batteries, battery life and maintenance, Li-ion batteries. **Nickel-based Batteries:** Nickel cadmium, Nickel metal hydride batteries. **Sodium-Based Batteries:**
Introduction, sodium sulphur batteries, sodium metal chloride (Zebra) batteries.
Lithium Batteries: Introduction, the lithium polymer battery, lithium ion battery.

Unit - II:

Battery charging strategies

Charging algorithms for a single battery: Basic terms for charging performance evaluation and characterization, CC charging for NiCd/NiMH batteries, CV charging for lead acid batteries, CC/CV charging for lead acid and Li-ion batteries, MSCC charging for lead acid, NiMH and Li-ion batteries, TSCC/CV charging for Li-ion batteries, CVCC/CV charging for Li-ion batteries, Pulse charging for lead acid, NiCd/NiMH and Li-ion batteries, Charging termination techniques, Comparisons of charging algorithms and new development; Balancing methods for battery pack charging: Battery sorting Overcharge for balancing, Passive balancing, Active balancing.

Unit -III:

Charging Infrastructure

Domestic Charging Infrastructure, Public charging Infrastructure, Normal Charging Station, Occasional Charging Station, Fast Charging Station, Battery Swapping Station, Move-and-charge zone.

Unit - IV:
Battery-Management-System Requirements
Battery-pack topology, BMS design requirements, Voltage sense, Temperature sense, Current sense, Contactor control, Isolation sense, Thermal control, Protection, Charger control, Communication via CAN bus, Log book, SOC estimation, Energy estimation, Power estimation, Diagnostics .

Unit - V:
Battery Modelling
General approach to modelling batteries, simulation model of rechargeable Li-ion battery, simulation model of a rechargeable NiCd battery, Parameterization of NiCd battery model, Simulation examples.

Text Books

1. Electric Vehicles Technology Explained by James Larminie Oxford Brookes University, Oxford, UK John Lowry Acenti Designs Ltd., Uk. (Unit-1)
2. Energy Systems for Electric and Hybrid Vehicles by K.T. Chau, IET Publications, First edition, 2016. (Unit-2)

Reference Books:

1. Modern Electric Vehicles Technology by C.C.Chan, K.T Chau, Oxford University Press Inc., New york , 2001. (Unit-3)
2. Battery Management Systems Vol. – II Equivalent Circuits and Methods, by Gregory L.Plett, Artech House publisher, First edition 2016. (Unit-4)
3. Battery Management Systems: design by Modelling by Henk Jan Bergveld, Wanda S. Kruijt, Springer Science & Business Media, 2002. (Unit-5)

II-Semester	POWER SYSTEM SIMULATION LABORATORY (LABORATORY – 3)	L	T	P	C
		0	1	2	2

Pre-requisite: Power System Analysis, Operation and Control.

Course Objectives:

- Understand the formation of Y-Bus and Z-Bus matrices for power system network modeling.
- Apply various load flow analysis methods including Gauss-Seidel, Newton-Raphson, and Fast Decoupled techniques.
- Analyze symmetrical and unsymmetrical faults using Z-Bus and sequence components.
- Perform Economic Load Dispatch with and without considering transmission losses.
- Study transient stability and load frequency control for single and multi-area power systems.

Course Outcomes:
After the completion of the course the student should be able to:

- Distinguish between different load flow methods.
- Building and analyzing Y-bus & Z-bus algorithms.
- Practice and analyze the symmetrical & unsymmetrical faults.
- Recognize the importance of Load frequency control and Economic load dispatch.
- Recognize the importance of transient stability analysis.

List of Experiments

Any 10 of the following experiments are to be conducted

1. Formation of Y- Bus by Direct-Inspection Method
2. Load Flow Solution Using Gauss-Siedel Method
3. Load Flow Solution Using Newton Raphson Method
4. Load Flow Solution Using Decoupled Method
5. Load Flow Solution Using Fast Decoupled Method
6. Formation of Z-Bus by Z-bus building algorithm
7. Symmetrical Fault analysis using Z-bus
8. Unsymmetrical Fault analysis using Z-bus
9. Economic Load Dispatch with & without transmission losses
10. Transient Stability Analysis Using Point By Point Method
11. Load Frequency Control of Single Area Control with and without controllers.
12. Load Frequency Control of Two Area Control system with and without controllers.

II-Semester	POWER CONVERTERS & DRIVES LABORATORY (LABORATORY – 4)	L	T	P	C
		0	1	2	2

Course Objectives:

- To understand the principles and operational characteristics of single-phase and three-phase converters, inverters, and their modulation techniques including unipolar, bipolar, SPWM, and space vector PWM.
- To apply various PWM control methods and vector control algorithms for speed regulation in induction motors, permanent magnet synchronous motors, brushless DC motors, and switched reluctance motors.
- To analyze the dynamic performance and control behavior of different inverter topologies, advanced modulation schemes, and vector/direct torque control strategies in motor drives.
- To evaluate the effectiveness of multilevel inverter modulation techniques and advanced motor control methods such as direct torque control and vector control for improved system efficiency and dynamic response.

Course Outcomes:

At the end of the course, the student will be able to.

- Understanding of converter and inverter operation, PWM techniques, and their effects on power quality and load characteristics.
- Apply modulation schemes and vector control principles to develop open-loop and closed-loop speed control of various motor drives effectively.
- Analyze waveforms, modulation patterns, and motor drive responses under different control schemes including rotor flux-oriented vector control and direct torque control.
- Evaluate the performance and suitability of advanced inverter and motor control methods, selecting optimal strategies for industrial drive applications.

Any 10 of the following experiments are to be conducted.

List of Experiments:

1. Analysis of single phase full converter with RL & RLE loads.
2. Analysis of three phase full converter with RL & RLE loads.
3. Analysis of single-phase full bridge inverter using unipolar & bipolar PWM techniques.
4. Analysis of three-phase two-level inverter for 120º & 180º mode of conduction.
5. Analysis of three phase two-level inverter using SPWM.
6. Analysis of three phase two-level inverter using space vector PWM.
7. Analysis of three phase three-level NPC inverter using SPWM
8. Analysis of Multicarrier PWM techniques for three-phase five-level cascaded H-bridge inverter.
9. Speed control of induction motor in open loop and closed loop using V/f method
10. Indirect vector control of induction motor with rotor field-oriented scheme.
11. Direct vector control of induction motor with rotor field-oriented scheme.
12. Switching table based direct torque control of induction motor.
13. Space vector modulation based direct torque control of induction motor.
14. Vector control of permanent magnet synchronous motor.
15. Speed control of brushless DC motor drive
16. Speed control of switched reluctance motor drive.

II-Semester	SEMINAR - II	L	T	P	C
		0	0	2	1

III-Semester	RESEARCH METHODOLGY AND IPR	L	T	P	C
		3	0	0	3

III-Semester	SUMMER INTERNSHIP/ INDUSTRIAL TRAINING (8-10 WEEKS)	L	T	P	C
		0	0	0	3

III-Semester	COMPREHENSIVE VIVA	L	T	P	C
		0	0	0	2

III-Semester	DISSERTATION PART – A	L	T	P	C
		0	0	20	10

IV-Semester	DISSERTATION PART – B	L	T	P	C
		0	0	32	16