DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

M.TECH COURSE STRUCTURE & SYLLABUS
Common to

I. Power Systems
II. Electrical Power Systems
III. Power Systems & Automation
IV. Electrical & Power Engineering
V. Power System Control & Automation
VI. Power Systems Control & Automation Engineering
VII. Electric Power System

(Applicable for batches admitted from 2025-2026)

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA

COURSE STRUCTURE

I Year M.Tech (Power Systems Group) I – Semester

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

I Year M.Tech (Power Systems Group) II – Semester

S. No.	Course Title	L	T	P	C
1	**Program Core – 4** Real Time Control of Power Systems	3	1	0	4
2	**Program Core – 5** Restructured Power Systems	3	1	0	4
3	**Program Core – 6** Flexible AC Transmission Systems	3	1	0	4
4	**Program Elective – III** i. Generation & Measurement of High Voltages ii. Evolutionary Algorithms in Power Systems iii. Energy Audit Conservation & Management	3	0	0	3
5	**Program Elective – IV** i. Power Quality Enhancement Using Custom Power Devices ii. Renewable Energy Technologies iii. Battery Management systems and charging stations	3	0	0	3
6	**Laboratory – 3** Power System Simulation Laboratory – II	0	1	2	2
7	**Laboratory – 4** Renewable Energy Technologies Laboratory	0	1	2	2
8	Seminar – II	0	0	2	1
	TOTAL	**15**	**5**	**6**	**23**

II Year MTech (Power Systems Group) 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 (Power Systems Group) II – Semester

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

% External Assessment

I Semester	POWER SYSTEM OPERATION & CONTROL (PROGRAM CORE – 1)	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	**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	REACTIVE POWER COMPENSATION AND MANAGEMENT (PROGRAM CORE – 3)	L	T	P	C
		3	1	0	4

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

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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	ADVANCED POWER SYSTEM PROTECTION (PROGRAM ELECTIVE–I)	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

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

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

Course Objectives:

- To learn various schemes of HVDC transmission.
- To explore various converter topologies and their terminal equipment
- To analyse control Techniques for HVDC systems.
- To evaluate the interaction between HVAC and HVDC system.
- To understand fault behaviour and various protection schemes in HVDC Systems.

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

- Analyse the limitations of EHVAC transmission and to enumerate the technical and economic advantages of HVDC transmission.
- Compare different converter configurations in HVDC transmission.
- Analyse the control strategies of HVDC Converters.
- Evaluate the interaction between HVAC and HVDC system.
- Identify the various protection schemes of HVDC systems.

UNIT – 1

Introduction: Limitation of EHV AC Transmission, Advantages of HVDC, Technical economical and reliability aspects. HVDC Transmission: General considerations, Power Handling Capabilities of HVDC Lines, Basic Conversion principles, static converter configuration. Types of HVDC links-Apparatus and its purpose

UNIT – 2

Static Power Converters: 6-pulse bridge circuit and 12-pulse converters, converter station and Terminal equipment, commutation process, Rectifier and inverter operation, equivalent circuit for converter – special features of converter transformers. Comparison of the performance of diametrical connection with 6-pulse bridge circuit

UNIT – 3

Control of HVDC Converters and systems: constant current, constant extinction angle and constant Ignition angle control. Individual phase control and equidistant firing angle control, DC power flow control. Factors responsible for generation of Harmonics voltage and current, harmonics effect of variation of α and μ. Filters, Harmonic elimination.

UNIT – 4

Interaction between HV AC and DC systems – Voltage interaction, Harmonic instability problems and DC power modulation. Development of DC circuit Breakers, Multi-terminal DC links and systems; series, parallel and series parallel systems, their operation and control.

UNIT – 5

Transient over voltages in HV DC systems: Over voltages due to disturbances on DC side, over voltages due to DC and AC side line faults. Converter faults and protection in HVDC Systems: Converter faults, over current protection - valve group, and DC line protection, circuit breakers. Over voltage protection of converters, surge arresters.

Text Books:

1. S Kamakshaih and V Kamaraju: HVDC Transmission- MG hill.
2. K.R.Padiyar : High Voltage Direct current Transmission, Wiley Eastern Ltd., New Delhi – 1992.

Reference Books:

1. E.W. Kimbark : Direct current Transmission, Wiley Inter Science – New York.
2. J.Arillaga : H.V.D.C.Transmission Peter Peregrinus ltd., London UK 1983
3. Vijay K Sood: HVDC and FACTS controllers: Applications of static converters in power systems by, Kluwer Academic Press.

I Semester	POWER ELECTRONIC CONVERTERS (PROGRAM ELECTIVE – II)	L	T	P	C
		3	0	0	3

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	PROGRAMMABLE LOGIC CONTROLLERS & APPLICATIONS (PROGRAM ELECTIVE–II)	L	T	P	C
		3	0	0	3

Pre-requisite: Boolean algebra and Basic of Microprocessor.

Course Objectives:

- To understand the various components of PLC systems and Input/output devices.
- To know the programming instructions and ladder diagram construction in the PLC.
- To understand the use and applications of timer and counter functions.
- To familiar the data handling function and their applications.
- To understand and implementation of analog operations and PID modules.

Course Outcomes:

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

- Illustrate I/O modules of PLC systems and Input/output devices.
- Demonstrate various the programming instructions and ladder diagram construction in the PLC.
- Examine various types of PLC functions and counters and their applications.
- Assess different data handling functions and its applications.

UNIT– 1

PLC Basics:

PLC system, I/O modules and interfacing, CPU processor, programming equipment, programming formats, construction of PLC ladder diagrams, devices connected to I/O modules.

UNIT– 2

PLC Programming:

Input instructions, outputs, operational procedures, programming examples using contacts and coils. Drill press operation. Digital logic gates, programming in the Boolean algebra system, conversion examples. Ladder diagrams for process control: Ladder diagrams and sequence listings, ladder diagram construction and flow chart for spray process system.

UNIT– 3

PLC Registers:

Characteristics of Registers, module addressing, holding registers, input registers, output registers. PLC Functions: Timer functions and Industrial applications, counters, counter function industrial applications, Arithmetic functions, Number comparison functions, number conversion functions.

UNIT– 4

Data Handling functions:

SKIP, Master control Relay, Jump, Move, FIFO, FAL, ONS, CLR and Sweep functions and their applications. Bit Pattern and changing a bit shift register, sequence functions and applications, controlling of two axis and three axis Robots with PLC, Matrix functions.

UNIT– 5

Analog PLC operation:

Analog modules and systems, Analog signal processing, multi bit data processing, analog output application examples, PID principles, position indicator with PID control, PID modules, PID tuning, PID functions.

Text Books:

1. Programmable Logic Controllers – Principle and Applications by John W. Webb and Ronald A. Reiss, Fifth Edition, PHI
2. Programmable Logic Controllers – Programming Method and Applications by JR. Hackworth and F.D Hackworth Jr. – Pearson, 2004.

Reference Books:

1. Introduction to Programmable Logic Controllers- Gary Dunning-Cengage Learning.
2. Programmable Logic Controllers –W.Bolton-Elsevier publisher.

I Semester	POWER SYSTEM SIMULATION LABORATORY – I	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.

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

II Semester	REAL TIME CONTROL OF POWER SYSTEMS (PROGRAM CORE – 4)	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	RESTRUCTURED POWER SYSTEM (PROGRAM CORE – 5)	L	T	P	C
		3	1	0	4

Pre-requisite: Knowledge on power systems.

Course Objectives:

- To introduce electricity market structures and architecture and evolution of electricity markets under different conditions and policy frameworks.
- To analyze different electricity sector ownership and management models.
- To study market mechanisms such as bilateral trading, power pools, LMP-based markets, and auction-based price formation methods.
- To understand the role of transmission networks in deregulated environments and examine concepts like market power, power wheeling, congestion management, and marginal transmission costing.
- To explore ancillary services and system security in deregulated power markets and review regulatory, technical, and economic challenges.

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

- Understand of operation of deregulated electricity market systems
- Typical issues in electricity markets
- Analyse various types of electricity market operational and control issues using new mathematical models.
- Understand LMP's wheeling transactions and congestion management.
- Analyse impact of ancillary services.

UNIT – 1

Need and conditions for deregulation: Introduction of Market structure, Market Architecture, Spot market, forward markets and settlements. Review of Concepts: marginal cost of generation, least-cost operation, incremental cost of generation. Power System Operation.

UNIT – 2

Electricity sector structures and Ownership /management: the forms of Ownership and management. Different structure model like Monopoly model, Purchasing agency model, wholesale competition model, Retail competition model.

UNIT – 3

Framework and methods for the analysis of Bilateral and pool markets, LMP based markets, auction models and price formation, price based unit commitment, country practices.

UNIT – 4

Transmission network and market power: Power wheeling transactions and marginal costing, transmission costing. Congestion management methods- market splitting, counter-trading; Effect of congestion on LMPs- country practices.

UNIT – 5

Ancillary Services and System Security in Deregulation: Classifications and definitions, AS management in various markets- country practices. Technical, economic, & regulatory issues involved in the deregulation of the power industry.

Text Books:

1. Power System Economics: Designing markets for electricity - S. Stoft, wiley.
2. Operation of restructured power systems - K. Bhattacharya, M.H.J. Bollen and J.E. Daalder, Springer.

Reference Books:

1. Market operations in electric power systems - M. Shahidehpour, H. Yaminand Z. Li,Wiley.
2. Fundamentals of power system economics - S. Kirschen and G. Strbac, Wiley.
3. Optimization principles: Practical Applications to the Operation and Marketsof the Electric
4. Power Industry - N. S. Rau, IEEE Press series on Power Engineeirng.
5. Competition and Choice in Electricity - Sally Hunt and Graham Shuttleworth

II Semester	FLEXIBLE AC TRANSMISSION SYSTEMS (PROGRAM CORE – 6)	L	T	P	C
		3	1	0	4

Pre-requisite: Concepts on Power Electronics and Power Systems

Course Objectives:

- Understand the need for FACTS devices in modern power systems to enhance transmission capability and stability.
- Gain knowledge about different types of FACTS controllers and their functionality.
- Study the operating principles of shunt and series compensators and their impact on power system operation.
- Analyze the role of voltage source and current source converters in FACTS applications.
- Explore advanced FACTS devices like UPFC and IPFC for comprehensive control of power flow.

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

- Explore the concept of FACTS and their importance in enhancing power system performance and stability.
- Compare voltage source converters (VSCs) and current source converters (CSCs) and describe their role in shunt compensation.
- Analyze the working principles and control strategies of shunt compensators like SVC and STATCOM.
- Evaluate the performance of series compensators such as TCSC, TSSC, and GSC in improving power transfer and system stability.
- Understand the operation of UPFC and IPFC and explain their role in real and reactive power flow control in transmission systems.

UNIT – 1

Introduction: FACTS concepts, Transmission interconnections, power flow in an AC System, loading capability limits, Dynamic stability considerations, importance of controllable parameters, basic types of FACTS controllers, benefits from FACTS controllers.

UNIT – 2

Basic concept of voltage and current source converters, comparison of current source converters with voltage source converters.

Static shunt compensation : Objectives of shunt compensation, midpoint voltage regulation, voltage instability prevention, improvement of transient stability, Power oscillation damping, methods of controllable VAr generation, variable impedance type static VAr generation, switching converter type VAr generation, hybrid VAr generation.

UNIT – 3

SVC and STATCOM: The regulation slope, transfer function and dynamic performance, transient stability enhancement and power oscillation damping, operating point control and summary of compensation control.

UNIT – 4

Static series compensators: Concept of series capacitive compensation, improvement of transient stability, power oscillation damping, functional requirements. GTO thyristor controlled series capacitor (GSC), thyristor switched series capacitor (TSSC), and thyristor controlled series capacitor (TCSC), control schemes for GSC, TSSC and TCSC.

UNIT – 5

Unified Power Flow Controller: Basic operating principle, conventional transmission control capabilities, independent real and reactive power flow control, comparison of the UPFC to series compensators and phase angle regulators. Introduction to Inter line Power Flow Controller (IPFC)

Text Books:

1. "Understanding FACTS Devices" N.G.Hingorani and L.Guygi, IEEE Press. Indian Edition is available:--Standard Publications

Reference Books:

1. Sang.Y.HandJohn.A.T, "Flexible AC Transmission systems" IEEE Press (2006).
2. HVDC & FACTS Controllers: applications of static converters in power systems- Vijay K.Sood- Springer publishers

II Semester	GENERATION AND MEASUREMENT OF HIGH VOLTAGES (PROGRAM ELECTIVE–III)	L	T	P	C
		3	0	0	3

Pre-requisite: Basics of Electrical circuits, Electronics and measurements for testing purpose.

Course Educational Objectives:

- To study the numerical methods for analysing electrostatic field problems.
- To study the fundamental principles of generation of high voltage for testing.
- To study the methods for measurement of high AC ,DC and transient voltages.
- To Study the measurement techniques for high AC ,DC and impulse currents.

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

- Understand numerical computation of electrostatic problems.
- Understand the techniques of generation of high AC, DC and impulse voltages and currents.
- Measure high AC, DC and transient voltages and currents.
- Measure impulse voltages and currents using voltage dividers, oscilloscopes, and other specialized instruments.

UNIT – 1

Electrostatic fields and field stress control: Electric fields in homogeneous Isotropic materials and in multi dielectric media-Simple configurations-field stress control. Methods of computing electrostatic fields-conductive analogues-Impedance networks Numerical techniques-finite difference method-finite element method and charge simulation method.

UNIT – 2

Generation of High AC & DC Voltages:

DC Voltages: AC to DC conversion methods, electrostatic generators, Cascaded Voltage Multipliers.

AC Voltages: Cascading transformers-Resonant circuits and their applications, Tesla coil.

UNIT – 3

Generation of Impulse Voltages:

Impulse voltage specifications-Impulse generation circuits-Operation, construction and design of Impulse generators-Generation of switching and long duration impulses.

Impulse Currents: Generation of high impulse currents and high current pulses.

UNIT – 4

Measurement of High DC & AC Voltages :

Measurement of High D.C. Voltages: Series resistance meters, voltage dividers and generating voltmeters.

Measurement of High A.C. Voltages: Series impedance meters electrostatic voltmeters potential transformers and CVTS-voltage dividers and their applications.

UNIT – 5

Measurement of Peak Voltages :

Sphere gaps, uniform field gaps, rod gaps. Chubb-Fortesque method, passive and active rectifier circuits for voltage dividers.

Measurement of Impulse Voltages: Voltage dividers and impulse measuring systems-generalized voltage measuring circuits-transfer characteristics of measuring circuits-L.V. Arms for voltage dividers-compensated dividers.

Measurement of Impulse Currents: Resistive shunts-current transformers-Hall Generators and Faraday generators and their applications-Impulse Oscilloscopes.

Text Books:

1. High Voltage Engineering – by E.Kuffel and W.S.Zaengl. Pergaman press Oxford, 1984.
2. High Voltage Engineering – by M.S.Naidu and V.Kamaraju, Mc.Graw-Hill Books Co., New Delhi, 2nd edition, 1995.

Reference Books:

1. High Voltage Technology – LL Alston, Oxford University Press 1968.
2. High Voltage Measuring Techniques – A. Schwab MIT Press, Cambridge,USA, 1972.
3. Relevant I.S. and IEC Specifications.

II Semester	EVOLUTIONARY ALGORITHMS IN POWER SYSTEMS (PROGRAM ELECTIVE–III)	L	T	P	C
		3	0	0	3

Pre-Requisite: i) Optimization Techniques ii) Power System Operation

Course Educational Objectives:

- To distinguish between conventional optimization algorithms and evolutionary optimization algorithms.
- To apply genetic algorithm and particle swarm optimization algorithm to power system.
- To analyse and apply Ant colony optimization algorithm and artificial Bee colony algorithm to optimize the control parameters of power system.
- To apply shuffled frog leaping algorithm and bat optimization algorithm to power system.
- To apply multi-objective optimization algorithm to power system.

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

- Classify and formulate different types of optimization problems and identify suitable soft computing techniques to solve them.
- Design and implement Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) for solving engineering problems like Economic Load Dispatch (ELD), harmonic elimination, and controller tuning.
- Apply and analyze Ant Colony Optimization (ACO) and Artificial Bee Colony (ABC) algorithms in real-time optimization scenarios.
- Evaluate and compare the performance of Bat Algorithm (BA) and Shuffled Frog-Leaping Algorithm (SFLA) for control and optimization applications.
- Solve multi-objective problems using Pareto optimality concepts and the NSGA-II algorithm to derive trade-off solutions among conflicting objectives.

UNIT– 1

Fundamentals of Soft Computing Techniques

Definition-Classification of optimization problems- Unconstrained and Constrained optimization Optimality conditions- Introduction to intelligent systems- Soft computing techniques- Conventional Computing versus Swarm Computing - Classification of meta-heuristic techniques - Single solution based
and population based algorithms – Exploitation and exploration in population based algorithms - Properties of Swarm intelligent Systems - Application domain - Discrete and continuous problems - Single objective and multi-objective problems.

UNIT– 2

Genetic Algorithm and Particle Swarm Optimization

Genetic algorithms- Genetic Algorithm versus Conventional Optimization Techniques - Genetic representations and selection mechanisms; Genetic operators- different types of crossover and mutation operators -Bird flocking and Fish Schooling – anatomy of a particle- equations based on velocity and positions -PSO topologies - control parameters – GA and PSO algorithms for solving ELD problem without loss, Selective Harmonic Elimination in inverters and PI controller tuning.

UNIT– 3

Ant Colony Optimization and Artificial Bee Colony Algorithms

Biological ant colony system - Artificial ants and assumptions - Stigmergic communications - Pheromone updating- local-global - Pheromone evaporation - ant colony system- ACO models-Touring ant colony system-max min ant system - Concept of Elitist Ants-Task partitioning in honey bees - Balancing foragers and receivers - Artificial bee colony (ABC) algorithms-binary ABC algorithms – ACO and ABC algorithms for solving Economic Dispatch without loss and PI controller tuning.

UNIT– 4

Shuffled Frog-Leaping Algorithm and Bat Optimization Algorithm

Bat Algorithm- Echolocation of bats- Behaviour of microbats- Acoustics of Echolocation- Movement of Virtual Bats- Loudness and Pulse Emission- Shuffled frog algorithm-virtual population of frogscomparison of memes and genes -memeplex formation- memeplexupdation- BA and SFLA algorithms for solving ELD without loss and PI controller tuning.

UNIT– 5

Multi Objective Optimization

Multi-Objective optimization Introduction- Concept of Pareto optimality - Non-dominant sorting technique-Pareto fronts-best compromise solution-min-max method-NSGA-II algorithm and application to general two objective optimization problem.

Text Books

1. Xin-She Yang, „Recent Advances in Swarm Intelligence and Evolutionary Computation", Springer International Publishing, Switzerland, 2015.
2. Kalyanmoy Deb „Multi-Objective Optimization using Evolutionary Algorithms", John Wiley & Sons, 2001.
3. James Kennedy and Russel E Eberheart, „Swarm Intelligence", The Morgan Kaufmann Series in Evolutionary Computation, 2001.

Reference Books:

1. Eric Bonabeau, Marco Dorigo and Guy Theraulaz, „Swarm Intelligence-From natural to Artificial Systems", Oxford university Press, 1999.
2. David Goldberg, „Genetic Algorithms in Search, Optimization and Machine Learning", Pearson Education, 2007.
3. Konstantinos E. Parsopoulos and Michael N. Vrahatis, „Particle Swarm Optimization and Intelligence: Advances and Applications", InformatIonscIence reference, IGI Global, , 2010.
4. N P Padhy, „Artificial Intelligence and Intelligent Systems", Oxford University Press, 2005.

Reference Papers:

1. "Shuffled frog-leaping algorithm: a memetic meta-heuristic for discrete optimization" by Muzaffareusuff, Kevin lansey and Fayzul pasha, Engineering Optimization, Taylor & Francis, Vol. 38, No. pp.129–154, March 2006.
2. "A New Metaheuristic Bat-Inspired Algorithm" by Xin-She Yang, Nature Inspired Cooperative Strategies for Optimization (NISCO 2010) (Eds. J. R. Gonzalez et al.), Studies in Computational Intelligence, Springer Berlin, 284, Springer, 65-74 (2010).
3. "Firefly Algorithms for Multimodal Optimization" Xin-She Yang, O. Watanabe and T. Zeugmann (Eds.), Springer-Verlag Berlin Heidelberg, pp. 169–178, 2009.

II Semester	ENERGY AUDIT CONSERVATION & MANAGEMENT (PROGRAM ELECTIVE–III)	L	T	P	C
		3	0	0	3

Pre-requisite: Electrical power systems and measurements.

Course Objectives:

- To understand the basics of energy audit and energy conservation schemes.
- To comprehend the principles of energy management and understand the need of energy efficient motors and lighting design practices.
- To study about power factor improvement techniques and energy instruments.
- To analyse the economic aspects of energy equipment.

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

- Understand the principle of energy audit and their economic aspects.
- Recommend energy efficient motors and design good lighting system.
- Understand advantages to improve the power factor.
- Evaluate the depreciation of equipment.

UNIT– 1

Basic Principles of Energy Audit

Energy audit- definitions, concept , types of audit, energy index, cost index ,pie charts, Sankey diagrams and load profiles, Energy conservation schemes- Energy audit of industries- energy saving potential, energy audit of process industry, thermal power station, building energy audit.

UNIT– 2

Energy Management

Principles of energy management, organizing energy management program, initiating, planning, controlling, promoting, monitoring, reporting. Energy manager, qualities and functions, language, Questionnaire – check list for top management

UNIT– 3

Energy Efficient Motors and Lighting

Energy efficient motors, factors affecting efficiency, loss distribution, constructional details, characteristics – variable speed , variable duty cycle systems, RMS - voltage variation-voltage unbalance-over motoring-motor energy audit. lighting system design and practice, lighting control, lighting energy audit

UNIT– 4

Power Factor Improvement and energy instruments

Power factor – methods of improvement, location of capacitors, Power factor with non-linear loads, effect of harmonics on p.f, p.f motor controllers – Energy Instruments- watt meter, data loggers, thermocouples, pyrometers, lux meters, tongue testers, application of PLC’s

UNIT– 5
Economic Aspects and their computation
Economics Analysis depreciation Methods, time value of money, rate of return, present worth method, replacement analysis, lifecycle costing analysis – Energy efficient motors. Calculation of simple payback method, net present value method- Power factor correction, lighting – Applications of life cycle costing analysis, return on investment.

Text Books:

1. Energy management by W.R.Murphy &G.Mckay Butter worth, Heinemann publications, 1982.
2. Energy management hand book by W.CTurner, John Wiley and sons, 1982.

Reference Books:

1. Energy efficient electric motors by John.C.Andreas, Marcel Dekker Inc Ltd-2nd edition,1995
2. Energy management by Paul o' Callaghan, Mc-graw Hill Book company-1st edition, 1998
3. Energy management and good lighting practice : fuel efficiency- booklet12-EEO

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 –Franciso 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	RENEWABLE ENERGY TECHNOLOGIES (PROGRAM ELECTIVE -IV)	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

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

Pre-Requisite: Basics of electrochemistry, circuit theory, 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-II	L	T	P	C
		0	1	2	2

Pre-requisite: Power systems analysis, operation and control.

Course Objectives:

- To utilize advanced analytical and computational approaches to evaluate and enhance the stability of multi-machine power systems.
- To apply optimal power flow techniques to improve system efficiency and analyze unit commitment strategies for cost-effective power generation.
- To conduct load flow studies and assess contingency scenarios to ensure the reliability and resilience of power systems.
- To implement state estimation techniques and power quality improvement strategies to maintain system reliability and performance.
- To analyze the stability of Single Machine Infinite Bus (SMIB) systems under different conditions, with and without controllers, to improve system dynamics.

Course Outcomes:

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

- Analyze the multi machine stability by advanced approaches.
- Calculate optimal power flows and analyze unit commitment by optimal methods.
- Analyze the load flow and contingency cases of power systems
- Analyze the state estimations and power quality improvements
- Analyze the stability of SMIB with and without controllers

List of experiments

Any 10 of the following experiments are to be conducted:

1. Multi Machine Transient stability using modified Euler's method.
2. Multi Machine Transient stability using R-K 2nd order method.
3. Optimal Power Flow using Newton's method.
4. Unit Commitment using dynamic programming.
5. Optimal Power Flow using Genetic Algorithm.
6. Distribution system load flow solution using Forward-Backward sweep Method.
7. Contingency analysis of a Power System
8. State estimation of a power system using Weighted Least Squares Error Method
9. Stability Analysis of SMIB using State space approach without PSS controller
10. Stability Analysis of SMIB using State space approach with PSS controller
11. Power Quality improvement using D-STATCOM

II Semester	RENEWABLE ENERGY TECHNOLOGIES LABORATORY -4	L	T	P	C
		0	1	2	2

Pre-requisite: Renewable Energy sources

Course objectives:

- To simulate and analyze the behaviour of solar PV cells and modules under different conditions.
- To study the impact of temperature, irradiation, resistance, and configurations on PV performance.
- To implement and understand MPPT techniques and DC-DC converter control in PV systems.
- To explore the working and performance characteristics of wind energy systems through simulation and experiments.
- To gain hands-on experience with solar and wind energy systems and observe real-time operational effects.

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

- Analyze the mathematical model and understand its solar PV cell characteristics.
- Demonstrate the effect of series and parallel combination of PV cells by I-V and P-V curves.
- Analyze the effect of suitable power electronic converters for PV system.
- Demonstrate the significance of various MPPT algorithms on PV System.
- Demonstrate wind power generation and wind turbine curves.
- Analyze the model of Uninterrupted Power Supply.

Any 5 of the following experiments are to be conducted from each part

Part A: Software Based List of Experiments:

1. Simulate the Mathematical Model of a PV cell using Single Diode model and Two Diode model equivalent circuits.
2. Simulate the performance curves (I-V & P-V) of a Solar cell and their variation with change in temperature and irradiation.
3. Simulate the performance curves (I-V & P-V) for PV modules connect in series and their variation with temperature and irradiation.
4. Simulate the performance curves (I-V & P-V) for PV modules connect in parallel and their variation with temperature and irradiation.
5. Simulate the performance curves (I-V & P-V) for the effect of varying the series resistance on the fill factor of the PV cell.
6. Simulate the Buck-Boost Converter with Closed Loop control.
7. Simulate the Maximum Power Point tracking of PV module using INC Algorithm.
8. Simulate the Maximum Power Point tracking of PV module using P & O Algorithm.

9. Simulate the Wind Power Plant model.
10. Simulate the Uninterrupted Power Supply model.

Part B: Hardware Based list of Experiments

Using Solar PV Training System:

11. Single PV module I-V and P-V characteristics with radiation and temperature changing effect.
12. I-V and P-V characteristics with series and parallel combination of modules.
13. Effect of shading on PV Module.
14. Effect of tilt angle on PV Module.
15. Demonstration of bypass and blocking diode on a PV Module.

Using Wind Energy Training System:

16. Evaluation of cut-in speed of wind turbine.
17. Evaluation of Tip Speed Ratio (TSR) at different wind speeds.
18. Evaluation of Coefficient of performance of wind turbine.
19. Characteristics of turbine (power variation) with wind speed.
20. Power curve of turbine with respect to the rotational speed of rotor at fix wind speeds.
21. Power analysis at turbine output with AC load for a Wind Energy System.

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