Ph.D. Electrical Engineering Scholars

All research scholars admitted to the Doctor of Philosophy (Ph.D.) program in Electrical Engineering under the Faculty of Engineering are required to select any one subject from the list of courses offered under PHD-102.

These subjects have been designed to strengthen the scholar's foundational and research-oriented understanding in specialized areas of Civil Engineering. The selected subject should align with the scholar's proposed area of research and must be approved by the Supervisor and the Departmental Research Committee (DRC).

The list of subjects offered under PHD-102 by the Department of Electrical Engineering is as follows:

S. No.	Faculty	Department / Branch	Subject Code	Name of Subject
1	Engineering & Technology	Electrical Engineering	PHD102EE01	Advanced Power System Engineering
2	Engineering & Technology	Electrical Engineering	PHD102EE02	Applications of Power Electronics in Power Systems
3	Engineering & Technology	Electrical Engineering	PHD102EE03	Advanced Course in Electrical Machines
4	Engineering & Technology	Electrical Engineering	PHD102EE04	SCADA Systems
5	Engineering & Technology	Electrical Engineering	PHD102EE05	Power System Operation and Control
6	Engineering & Technology	Electrical Engineering	PHD102EE06	Renewable Energy Systems and Smart Grid Technologies
7	Engineering & Technology	Electrical Engineering	PHD102EE07	Advanced Control Systems and Applications
8	Engineering & Technology	Electrical Engineering	PHD102EE08	Power Electronics and Electric Drives
9	Engineering & Technology	Electrical Engineering	PHD102EE09	High Voltage Engineering and Insulation Technology
10	Engineering & Technology	Electrical Engineering	PHD102EE10	Artificial Intelligence and Machine Learning Applications in Electrical Engineering

Program	Faculty	Branch/Specialization	Name of Subject	Subject Code
Ph.D	Engineering & Technology	Electrical Engineering	Advanced Power System Engineering	PHD102EE01

Course Outcomes:

1. Understand the fundamentals of power system stability and dynamic behavior.
2. Develop mathematical models for synchronous machines and excitation systems.
3. Analyze system response using small signal and transient stability studies.
4. Apply techniques for power system control, protection, and stabilization.
5. Evaluate modern digital protection schemes and adaptive relaying applications.

Unit-wise Content distribution

Unit	Contents
Unit-I	INTRODUCTION TO POWER SYSTEM STABILITY PROBLEM: Basic concepts and definitions: Rotor angle stability, voltage stability and voltage collapse, Midterm and long-term stability, Classification of stability, states of operation and system security system dynamic problems. REVIEW OF CLASSICAL METHOD: System model, some mathematical analysis of steady state stability, analysis of transient stability, simplified representation of excitation control.
Unit-II	MODELING OF SYNCHRONOUS MACHINE: Introduction, synchronous machine, parks transformation, analysis of steady state performance per unit equivalent circuits of synchronous machine, determination of parameters of equivalent circuits, measurements for obtaining data, saturation models, transient analysis of a synchronous machine EXCITATION AND PRIME MOVER CONTROLLERS: Excitation system Modeling, system representation by state evasions, prime move control systems.
Unit-III	TRNMISSION LINE, SVC AND LOADS: D-Q transformation using L-B variables, static var compensators, loads Dynamics of a synchronous generator connected to estimate bus: system model, synchronous machine model, calculation of initial conditions, inclusion of SVC Model, Analysis of single machine system, Small signal analysis with block diagram representation, synchronizing and damping torque analysis, small signal model, nonlinear oscillators. APPLICATION OF POWER SYSTEM STABILIZERS: Basic concepts, control signals, structure and tuning of PSS, field implementation and operating experience 8 Hours.

Unit-IV	Protective Relays: Relaying review, characteristics and operating equations of relays. CT's and PT's differential relay, over-current relay, reverse power relay, distance relays, applications of relays. STATIC RELAYS: Introduction, advantages and disadvantages, classification logic ckts, smoothing circuits, voltage regulator square wave generator, time delay ckts level detectors, summation device, sampling circuit, zero crossing detector, output devices. COMPARATORS: Replica Impedance, mixing transformers, general equation of phase and amplitude comparator, realization of ohm, impedance and off set impedance characteristics, duality principle, static amplitude comparators, coincidence circuit, Hall effect devices, Magneto receptivity, zener diode phase comparator multi input comparators.
Unit-V	Generator and transformer protection: Protective devices for system. Protective devices for stator, rotor, and prime mover of generator, percentage differential relays protection, three winding transformer protection, earth fault protection, generator transformer unit protection. Bus bar and transmission line protection: Distance protective schemes, directional wave detection relay. Phase compensation carrier protection. High impedance differential scheme, supervisory and check relay, Some features of 500 KV relaying protection. Modern trends in power system protection: Different types of digital and computer aided relays, Microprocessor based relays, auto-reclosing, frequency relays, under and over frequency relays, di/dt relays. Algorithms for transmission line, transformer & bus bar protection; out-of-step relaying Introduction to adaptive relaying & wide area measurements

Textbooks/References:

1. K.R. Padiyar, Power system dynamics, stability and control, BS Pub. Hydbd
2. P Kunder, Power system stability and control, TMH.
3. P. W. Sauer & M A Pai: Power system dynamics and stability: Pearson.
4. Power System Protection and Switchgear, B.Ram – Tata Mc-Graw Hill Pub.
5. Switchgear and Protection, M.V.Deshpande - Tata Mc-Graw Hill Pub.
6. Power System Protection & Switchgear, Ravindra Nath, M.Chander, Willy P

Program	Faculty	Branch/Specialization	Name of Subject	Subject Code
Ph.D	Engineering & Technology	Electrical Engineering	Applications of Power Electronics in Power System	PHD102EE02

Course Outcomes:

1. Understand the modeling and analysis of power system components and their interactions.
2. Apply reactive power compensation and control techniques for system performance enhancement.
3. Analyze system stability using FACTS devices and voltage stability indicators.
4. Design and assess various FACTS controllers such as SVC and TCSC for dynamic control.
5. Integrate power electronic devices for reliability improvement and flexible system operation.

Unit-wise Content distribution

Unit	Contents
Unit-I	Power System components models formation of bus admittance matrix, algorithm for formation of bus impedance matrix. Reactive power capability of an alternator, transmission line model & loadability, Reactive power transmission & associated difficulties, Regulated shunt compensation, Models of OLTC & Phase shifting transformer, load flow study.
Unit-II	Sensitivity analysis: Generation shift distribution factors, line outage distribution factors, Compensated shift factors. Power systems security levels, contingency selection & evaluation, security constrained economic dispatch. Pre-contingency corrective rescheduling.
Unit-III	Voltage stability: Proximity indicators e.g. slope of PV curve, Minimum Eigen value of reduced load flow Jacobian participation factors based on modal analysis and application.
Unit-IV	Flexible ac transmission system, reactive power control, brief description and definition of FACT's controllers, shunt compensators, configuration and operating characteristics of TCR, FC-TCR, TSC, Comparisons of SVCs
Unit-V	Thy thyristor controlled series capacitor (TCSC) Advantages of the TCSC, Basic principle and different mode of operation, analysis variable reactance model and transient stability model of TCSC.

Textbooks/References:

1. Modern power system analysis D.P. Kothari, I.J. Nagrath, TMH, 2003
2. Power generation operation and control, A.J. Wood, B.F Woolenberg, John W
3. Understanding facts: Concepts and technologies of flexible AC transmission system IEEE Press, 2001 N.G. Hingorani, L. Gyugyi
4. Power system stability and control IEEE press P. Kundur, 1994
5. Thyristor Based FACTS controllers for electrical Transmission systems- R.M. Mathur, R.K. Verma, Wieldy inter science, 2002

Program	Faculty	Branch/Specialization	Name of Subject	Subject Code
Ph.D	Engineering & Technology	Electrical Engineering	Advance Course in Electrical Machines	PHD102EE03

Course Outcomes:

1. Understand the general theory and dynamic modeling of electrical machines.
2. Analyze steady-state and transient performance of DC, induction, and synchronous machines.
3. Apply Park's transformation and operational impedance methods for system analysis.
4. Evaluate machine parameters, time constants, and equivalent circuit representations.
5. Employ approximate and computational methods for generator and system fault analysis.

Unit-wise Content distribution

Unit	Contents
Unit-I	Review: Primitive machine, voltage and torque equation. Concept of transformation, change of variables, m/c variables and transform variables. Application to D.C. machine for steady state and transient analysis, equation of cross field commutator machine
Unit-II	Induction Machine: Voltage, torque equation for steady state operation, Equivalent circuit, Dynamic performance during sudden changes in load torque and three phase fault at the machine terminals. Voltage & torque equation for steady state operation of 1-ö induction motor & scharge motor.
Unit-III	Synchronous Machine: Transformation equations for rotating three phase windings, Voltage and power equation for salient and non salient alternator, their phasor diagrams, Simplified equations of a synchronous machine with two damper coils.
Unit-IV	Operational Impedances and Time Constants of Synchronous Machines : Park's equations in operational form, operational impedances and G(P) for a synchronous machine with four Rotor Windings, Standard synchronous machine Reactances, time constants, Derived synchronous machine time constants, parameters from short circuit characteristics.
Unit-V	Approximate Methods for Generator & System Analysis: The problem of power system analysis, Equivalent circuit & vector diagrams for approximate calculations, Analysis of line to line short circuit, Application of approximate method to power system analysis.

Textbooks/References:

1. Analysis of Electric Machinery - P.C.Krause
2. The General theory of Electrical Machines - B.Adkins
3. The General theory of AC Machines - B.Adkins & R.G.Harley
4. Generalised theory of Electrical m/c - P.S.Bhimbra
5. Electro Mechanical Energy Conversion - White & Woodson

Program	Faculty	Branch/Specialization	Name of Subject	Subject Code
Ph.D	Engineering & Technology	Electrical Engineering	SCADA Systems	PHD102EE04

Course Outcomes:

1. Understand the architecture, components, and functionality of SCADA systems.
2. Apply knowledge of telemetry, data acquisition, and communication protocols in control systems.
3. Analyze the role of automation and distribution control in modern power systems.
4. Implement SCADA security protocols and assess vulnerabilities in industrial networks.
5. Explore smart grid integration, PMUs, and communication technologies for future energy systems.

Unit-wise Content distribution

Unit	Contents
Unit-I	SCADA SYSTEM: Need of computer control of power systems, Data acquisition and control, SCADA System evolution, SCADA System architecture, SCADA System desirable properties, Remote Terminal Unit- RTU Principle, Test and configuration tools for RTU, SCADA human – machine interface (HMI)
Unit-II	SCADA COMMUNICATION - Transducers- Analog and Digital transducers, Digital data acquisition systems, Signal conditioning system, Data telemetry- Voltage and current telemetry, Position telemetry , radio frequency telemetry, Transmission channels and media
Unit-III	SCADA Protocols- Evolution of SCADA Protocols, Proprietary and open protocols , OSI Model, TCP/IP Model, Modbus, DNP3, UCA, IEC 61850 Standards, SCADA security system
Unit-IV	Automatic Substation Control and Distribution Automation : Topology and functionality, hardware implementation , system configuration and testing, Factors influencing the application of automation of distribution networks, Primary and secondary distribution network automation, Autoreclosers , Sectionalizers , Ring Main Units (RMU) ,Fault passage Indicators (FPI)
Unit-V	Smart Grid- Principle and architecture of Smart Grid, Self healing and adaptive grids, Key drivers, components of smart grid, smart grid management center, Advance metering infrastructure for smart grid , Zigbee and home area network (HAN), Phasor measurement unit (PMU), smart grid security , India's initiative and development toward smart grid , challenges in smart grid implementation.

Textbooks/References:

1. SCADA: Supervisory Control and Data Acquisition - Stuart A. Boyer , ISA publisher
2. Practical Modern SCADA Protocols-Gordon Clarke and Deon Reynders, Newnes publisher
3. Cybersecurity for SCADA Systems-William T Shaw , PennWell Books
4. GIS - SCADA Integration: Approach for Power Distribution-Priyanka Verma and Sumit

Verma , LAP Lambert Academic Publishing
5. Securing SCADA Systems-Ronald L. Krutz, John Wiley & Sons
6. Designing SCADA Application Software-Stuart G. McCrady, Elsevier Science Publishing Co Inc
7. Control and Automation of Electrical Power Distribution Systems- James Northcote-Green and Robert G. Wilson , CRC Press
8. Smart Grid Fundamentals of design and analysis - James Momoh, Wiley-Blackwell publisher

Program	Faculty	Branch/Specialization	Name of Subject	Subject Code
Ph.D	Engineering & Technology	Electrical Engineering	Power System Operation and Control	PHD102EE05

Course Outcomes:

1. Understand the objectives and challenges of power system operation and control.
2. Model and analyze load frequency and voltage control systems in interconnected networks.
3. Apply optimization and control techniques for economic and secure system operation.
4. Evaluate system security and integrate reactive power and renewable generation control.
5. Utilize modern AI and smart grid technologies for advanced power system management.

Unit-wise Content distribution

Unit	Contents
Unit-I	**Introduction to Power System Operation** Structure and components of modern power systems. Power system operation stages – scheduling, dispatch, and control hierarchy. Objectives of power system operation – economy, security, and reliability. Load forecasting – short-term, medium-term, and long-term methods. Economic load dispatch – classical and modern approaches, transmission losses, penalty factors, and lambda iteration method.
Unit-II	**Load Frequency Control (LFC)** Fundamentals of frequency control and tie-line bias control. Modeling of single-area and multi-area load frequency control systems. Governor speed regulation and frequency response characteristics. Automatic Generation Control (AGC) and load-frequency control design. Integration of renewable energy sources and impact on frequency regulation.
Unit-III	**Reactive Power and Voltage Control** Reactive power requirements and voltage profile management. Methods of voltage control – tap-changing transformers, capacitor banks, and synchronous condensers. Reactive power compensation – shunt and series devices. Use of FACTS controllers (SVC, STATCOM, TCSC) in voltage and reactive power control. Dynamic stability enhancement through reactive power management.
Unit-IV	**Power System Security and Economic Operation** Concept of power system security – monitoring, contingency analysis, and preventive control.Power system state estimation and measurement redundancy. Optimal power flow (OPF) – formulation, constraints, and solution methods. Security-constrained OPF and economic dispatch considering transmission limits. Role of SCADA and EMS in secure power system operation.
Unit-V	**Advanced Control Techniques and Smart Grid Integration** Intelligent and adaptive control strategies in power system operation. AI and machine learning applications for load forecasting and dispatch. Wide Area Measurement Systems (WAMS) and Phasor Measurement Units (PMU). Smart grid technologies – integration of distributed energy resources and demand response. Future trends in autonomous and resilient power system operation.

Recommended Books / References:

1. Allen J. Wood, Bruce F. Wollenberg, and Gerald B. Sheble, *Power Generation, Operation, and Control*, Wiley, 3rd Edition, 2013.
2. O.I. Elgerd, *Electric Energy Systems Theory: An Introduction*, Tata McGraw Hill, 2nd Edition, 2006.
3. P.S.R. Murty, *Operation and Control in Power Systems*, BS Publications, 2011.
4. Leon K. Kirchmayer, *Economic Operation of Power Systems*, Wiley, 2018 (Reprint).
5. J. Duncan Glover, Mulukutla S. Sarma, and Thomas Overbye, *Power System Analysis and Design*, Cengage Learning, 6th Edition, 2022.
6. N. K. Jain and A. K. Singh, *Power System Operation and Control*, McGraw Hill Education, 2020.

Program	Faculty	Branch/Specialization	Name of Subject	Subject Code
Ph.D	Engineering & Technology	Electrical Engineering	Renewable Energy Systems and Smart Grid Technologies	PHD102EE06

Course Outcomes:

1. Understand the operation and control of renewable energy systems.
2. Design hybrid and grid-connected renewable systems.
3. Apply power electronics and storage for renewable energy management.
4. Analyze the architecture and operation of smart grids and microgrids.
5. Evaluate policies and technologies for sustainable energy systems.

Unit-wise Content distribution

Unit	Contents
Unit-I	**Introduction to Renewable Energy Systems** Energy scenario and need for renewable energy. Classification and principles of renewable sources – solar, wind, biomass, hydro, and geothermal. Overview of energy conversion systems and power conditioning. Distributed generation and grid interconnection concepts.
Unit-II	**Solar and Wind Energy Systems** Solar photovoltaic and thermal power generation systems. Design of solar PV systems, MPPT algorithms, and grid connectivity. Wind turbine principles, aerodynamics, and control strategies. Hybrid solar–wind systems and integration challenges.
Unit-III	**Energy Storage and Power Electronics Interface** Energy storage technologies – batteries, supercapacitors, and flywheels. Power electronics converters for renewable integration – DC–DC, DC–AC, and multilevel inverters. Control of grid-connected inverters and voltage/frequency regulation. Reactive power management and power quality improvement.
Unit-IV	**Smart Grid and Microgrid Concepts** Architecture and components of smart grids.Communication protocols, sensors, and smart meters. Microgrid design, operation, and control.Demand response, distributed generation management, and peer-to-peer energy trading.
Unit-V	**Emerging Trends and Case Studies** Integration of EVs, IoT, and AI in smart grids. Cybersecurity in energy systems. Case studies of renewable-based microgrids in India and abroad. Policy and regulatory framework for renewable integration.

Reference Books:

1. S. A. Kalogirou, *Solar Energy Engineering: Processes and Systems*, Academic Press, 2013.
2. B. K. Bala & M. A. Sattar, *Renewable Energy and the Environment*, CRC Press, 2020.

3. B. K. Bose, *Power Electronics and Motor Drives*, Academic Press, 2010.
4. J. Momoh, *Smart Grid: Fundamentals of Design and Analysis*, Wiley, 2012.
5. S. Chowdhury et al., *Microgrids and Active Distribution Networks*, IET Press, 2009.

Program	Faculty	Branch/Specialization	Name of Subject	Subject Code
Ph.D	Engineering & Technology	Electrical Engineering	Advanced Control Systems and Applications	PHD102EE07

Course Outcomes:

1. Develop mathematical models using state-space representation.
2. Design optimal and robust control systems for practical applications.
3. Apply nonlinear and adaptive control techniques.
4. Implement intelligent control algorithms using AI and fuzzy systems.
5. Analyze real-world control systems using modern computational tools.

Unit-wise Content distribution

Unit	Contents
Unit-I	**State-Space and Modern Control Theory** State-space representation and modeling. Controllability, observability, and stability analysis. Pole placement and state feedback control. Discrete-time control systems and digital implementation.
Unit-II	**Optimal and Robust Control Systems** Optimal control formulation using performance indices. Linear Quadratic Regulator (LQR) and Riccati equation solutions. $H\infty$ and μ-synthesis methods for robust control. Sensitivity and robustness analysis in control systems.
Unit-III	**Nonlinear and Adaptive Control Systems** Phase-plane, describing function, and Lyapunov stability. Model reference adaptive systems (MRAS) and self-tuning regulators. Adaptive control in electrical drives and process control.
Unit-IV	**Intelligent Control Techniques** Fuzzy logic control – fuzzification, defuzzification, and inference mechanisms. Artificial neural networks and their applications in control. Genetic algorithms and evolutionary computation in optimization. Hybrid intelligent control techniques.
Unit-V	**Applications and Case Studies** Control applications in power systems, robotics, and renewable integration. AI-based predictive and model-free control systems. Case studies of modern control in automation and energy systems.

Reference Books:

1. K. Ogata, *Modern Control Engineering*, Prentice Hall, 2010.
2. B. C. Kuo & F. Golnaraghi, *Automatic Control Systems*, Wiley, 2017.
3. D. Driankov, *Fuzzy Logic Control*, Springer, 1993.
4. K. S. Narendra & A. M. Annaswamy, *Adaptive Control*, Prentice Hall, 2012.
5. Frank L. Lewis, *Optimal Control*, Wiley, 2013.

Program	Faculty	Branch/Specialization	Name of Subject	Subject Code
Ph.D	Engineering & Technology	Electrical Engineering	Power Electronics and Electric Drives	PHD102EE08

Course Outcomes:

1. Understand converter topologies and semiconductor device characteristics.
2. Design and control DC and AC drives for industrial and EV applications.
3. Apply PWM and modulation techniques for converter control.
4. Evaluate performance of drives using digital and AI control.
5. Explore power electronic systems for energy-efficient technologies.

Unit-wise Content distribution

Unit	Contents
Unit-I	**Power Semiconductor Devices and Converters** Characteristics of IGBT, MOSFET, and GTO. Single-phase and three-phase converters – controlled and uncontrolled. DC–DC converters and AC voltage controllers. PWM techniques and harmonic reduction..
Unit-II	**Inverters and Multilevel Converters** Single-phase and three-phase inverters. Voltage source and current source inverters. Multilevel inverter configurations and control methods. Matrix converters and bidirectional power flow.
Unit-III	**Control of DC Drives** Modeling of DC motors and converters. Speed control using armature voltage and field control. Four-quadrant operation, chopper-fed DC drives. Closed-loop control and dynamic analysis.
Unit-IV	**Control of AC Drives** Induction motor modeling and vector control. Direct torque control (DTC) and scalar control. Synchronous motor drives and BLDC motor drives. Sensorless control and regenerative braking.
Unit-V	**Applications and Emerging Trends** Electric and hybrid electric vehicles. Renewable energy integration and battery management. Digital control of drives using DSPs and microcontrollers. AI-based predictive control of power converters.

Reference Books:

1. B. K. Bose, *Modern Power Electronics and AC Drives*, Pearson, 2002.
2. P. C. Sen, *Power Electronics*, Tata McGraw Hill, 1998.
3. R. Krishnan, *Electric Motor Drives: Modeling, Analysis and Control*, Prentice Hall, 2001.

4. M. H. Rashid, *Power Electronics: Circuits, Devices and Applications*, Pearson, 2013.
5. G. K. Dubey, *Fundamentals of Electrical Drives*, Narosa, 2009.

Program	Faculty	Branch/Specialization	Name of Subject	Subject Code
Ph.D	Engineering & Technology	Electrical Engineering	High Voltage Engineering and Insulation Technology	PHD102EE09

Course Outcomes:

1. Understand breakdown phenomena and insulation principles.
2. Generate and measure high voltages for testing applications.
3. Apply insulation coordination and design methods.
4. Evaluate high voltage equipment performance using international standards.
5. Explore modern materials and monitoring technologies for insulation systems.

Unit-wise Content distribution

Unit	Contents
Unit-I	**Introduction to High Voltage Engineering** Need and importance of high voltage systems. Electric field stress analysis and control. Breakdown in gases, liquids, and solid dielectrics. Partial discharge and insulation aging mechanisms.
Unit-II	**Generation and Measurement of High Voltages** Generation of high DC, AC, and impulse voltages. Test transformers and voltage dividers. Measurement of high voltage and currents – resistive, capacitive, and potential dividers. Digital techniques for HV measurement.
Unit-III	**Insulation Design and Coordination** Insulation coordination and dielectric strength. Creepage distance, pollution flashover, and insulation grading. Protection systems against overvoltage and lightning. Design of insulation for switchgear and transformers.
Unit-IV	**Testing of High Voltage Equipment** Impulse and power frequency testing of cables, transformers, insulators, and circuit breakers. Non-destructive testing methods.High voltage test circuits and standards (IEC, IS). Condition monitoring and life estimation.
Unit-V	**Modern Trends in Insulation Technology** Nanodielectrics, polymer composites, and gas-insulated systems. Smart insulation materials and self-healing dielectrics. AI and sensor-based insulation monitoring systems. High voltage research in renewable and HVDC systems.

Reference Books:

1. E. Kuffel & W. S. Zaengl, *High Voltage Engineering Fundamentals*, Elsevier, 2012.
2. M. S. Naidu & V. Kamaraju, *High Voltage Engineering*, McGraw Hill, 2013.
3. R. Arora & W. Mosch, *High Voltage and Electrical Insulation Engineering*, Wiley, 2011.
4. Dieter Kind, *High Voltage Test Techniques*, Elsevier, 2001.
5. Adamiak, M., *Modern Trends in High Voltage Engineering*, IEEE Press, 2020.

Program	Faculty	Branch/Specialization	Name of Subject	Subject Code
Ph.D	Engineering & Technology	Electrical Engineering	Artificial Intelligence and Machine Learning Applications in Electrical Engineering	PHD102EE10

Course Outcomes:

1. Understand AI and ML fundamentals for engineering applications.
2. Apply AI algorithms for system control, optimization, and fault detection.
3. Use ML models for power forecasting and grid management.
4. Integrate deep learning for automation and smart grid operation.
5. Conduct AI-driven research for advanced energy and industrial systems.

Unit-wise Content distribution

Unit	Contents
Unit-I	**Fundamentals of AI and Machine Learning** Overview of AI concepts, knowledge representation, and search algorithms. Machine learning paradigms – supervised, unsupervised, and reinforcement learning. Data preprocessing, feature extraction, and model evaluation.
Unit-II	**AI in Power System Analysis** Load forecasting using ANN and regression models. Fault detection and diagnosis using pattern recognition. Voltage stability and security assessment using ML. Optimization in power dispatch using evolutionary algorithms.
Unit-III	**AI in Control and Automation** Fuzzy logic controllers, neural network control, and adaptive control systems. Predictive control and optimization of industrial processes. AI-based PID tuning and system identification.
Unit-IV	**AI in Renewable Energy and Smart Grids** Solar and wind power forecasting using ML models. Energy management and demand response systems. Fault prediction in inverters and battery systems. AI for grid stability and distributed energy resource optimization.
Unit-V	**Deep Learning and Emerging Research** Introduction to CNNs, RNNs, and reinforcement learning. Applications in robotics, EVs, and smart grid resilience. Case studies using TensorFlow, MATLAB, and Python frameworks. Recent research directions in AI-enabled power systems.

Reference Books:

1. S. Rajasekaran & G. A. Vijayalakshmi Pai, *Neural Networks, Fuzzy Logic, and Genetic Algorithms*, PHI, 2017.
2. Stuart Russell & Peter Norvig, *Artificial Intelligence: A Modern Approach*, Pearson, 2021.
3. Stephen J. Chapman, *MATLAB Programming for Engineers*, Cengage, 2016.
4. Timothy Masters, *Practical Neural Network Recipes in C++*, Academic Press, 1993.
5. Ian Goodfellow, Yoshua Bengio & Aaron Courville, *Deep Learning*, MIT Press, 2016.